User Manual
v1.00

Photon Transport Simulator

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Introduction

Background

This User Manual describes the basic operation of the Photon Transport Simulator (PTS) program written by Nick Pfeiffer for use in investigating photon transport through scattering and absorbing media. It describes the latest version of the PTS software (m1main12.exe, June 11, 2006).

The PTS software is a ray trace/Monte Carlo photon simulator. It was originally developed in October 2002 and has been steadily modified as required to allow Nick Pfeiffer to investigate photon transport problems. It is considered to be a working tool, and, as such, is expected to be changed and extended as needed.

The PTS software is written in ANSI C and compiled using a Borland C compiler. The source code is self-documenting and should be self-explanatory when used in conjunction with the following reports:

Nick Pfeiffer, *Development of Software Tools for Simulation of Photon Transport in Scattering and Absorbing Media: the Photon Transport Simulator*, SFU, ENSC 892 Major Project, Dec 28, 2002.

Nick Pfeiffer, *Development of NURB Surface and Visualization Extensions to the Photon Transport Simulator*, SFU, ENSC 889 Major Project, Apr 10, 2003.

This User Guide is designed to provide a quick introduction to the PTS software and to act as a command/syntax reference. Users are referred to the above reports for additional details. In this User Guide, references have been removed - see above reports for original references.

The PTS software is believed to function as indicated, however not all features have been exhaustively tested and no claim is given for absolute reliability or correctness. Users are cautioned to check output for reasonableness and to confirm new geometries etc. with simple test cases.

Software Methodology

The PTS software uses a ray trace/Monte Carlo method to simulate photons. The software is geometry-based and allows the creation of multiple, arbitrary three-dimensional (3D) media, multiple photons sources, and multiple photon detectors.

Briefly, a photon is launched from a defined photon source and travels in a straight-line until it is scattered or intersects the face of a medium. If it is scattered, then a new photon direction is determined based upon the phase function. If it intersects a medium, then a new photon direction is determined based upon Fresnel reflection/refraction at the boundary. Whenever a photon is scattered or reflected/refracted, a check is done to determine whether the photon was absorbed. If the photon was absorbed, then its life is terminated. If a photon is not absorbed, then it continues until it is absorbed. If a photon passes through a detector, then some characteristics of the photon are recorded.

Media (3D objects) are defined as blocks, cylinders, or semi-spheres. The order in which objects are defined is important, as the last object defined determines the characteristics of the medium. In this approach a fish tank would be defined by first defining a block of air, then defining a block of glass inside the block of air, then defining a block of water inside the block of glass. The photon will check its current position at each scattering/refraction/reflection event and use the optical properties of the last defined medium within which it finds itself. This approach allows complex objects (diverging lenses, collimating holes, etc. to be defined as combinations of simple primitives (blocks, cylinders, semi-spheres).

The PTS software does not inherently support complex optical devices such as lenses mirrors, etc. However, because it is geometry-based, creating mediums with a lens shape and the correct optical properties, will create a lens. Similarly, creating a block with high index of refraction, will create a mirror (due to Fresnel reflection) and creating a hole of vacuum through an absorbing medium will create a collimating hole, etc.

Input to the PTS software is done through a text file (generally with the extension .mci for Monte Carlo input). A well-defined syntax is used to specify mediums, photons sources, and detectors (photon density maps). The input text file is in human-readable format.

Output from the PTS software is done through two forms of output text files. The first output form (with the extension .mco for Monte Carlo output) is identical to the input form with additional information added. Again, it is human-readable and allows a simple check to confirm that the input file(s) were processed correctly. The second output form (with the extension .scm for Scheme) is designed to create a 3D model of the geometry (mediums, photon sources, detectors, and specified photon paths). This text file is actually a set of Scheme commands and is designed to be processed by the Scheme editor in ACIS to create the geometry. For details on loading the Scheme commands and viewing the resulting model, please see the ACIS documentation (SFU has a site license for ACIS).

Basic Scattering Theory

The basic equation that governs the steady state scattering of monochromatic light in a homogenous medium is the Boltzmann transport equation.

$$\nabla \bullet \Psi(r,O) + \mu_t(r)\Psi(r,O) = \int \mu_s S(?)\Psi(r,O')dO' + Q(r,O')$$

where:

O = photon direction after a scattering event

O' = photon direction before a scattering event

$\Psi(r,O)$ = radiance at position *r* in direction O

$\mu_t = \mu_s + \mu_a$ = total interaction coefficient (also referred to as the extinction coefficient)

μ_s = scattering coefficient

μ_a = absorption coefficient

$S(?)$ = phase function, normalized angular distribution of scattering

$Q(r,O')$ = source density

The Boltzmann equation has been solved analytically for a few simple geometries. When the absorption is small compared to the scattering, a diffusion theory approximation of the Boltzmann equation is often employed. However, for arbitrarily complex geometries, of the kind found in optical tomography applications, the Boltzmann equation cannot be solved analytically. In these instances numerical simulation, primarily those based upon Monte Carlo modeling, is employed to generate highly accurate results.

For interstellar mediums, a phase function *S*(*?*) that describes the experimentally observed distribution of scattering angles of photons was developed by Henyey and Greenstein. It has been found by Jacques et al that the Henyey-Greenstein phase function *S*(*?*) also accurately describes the scattering of light in biological tissue. The important parameter of this phase function is *g*, the cosine of the forward scattering angle. Values of *g* can vary from –1 to 1, with 0 representing uniform scattering and values close to 1 representing a high degree of forward scattering. Many common biological tissues have a high degree of forward scattering, with *g* values ranging from 0.79 to 0.98 for 633 nm wavelength photons.

At present the PTS software only supports the Henyey-Greenstein phase function.

The Henyey-Greenstein (HG) function is

$$S(?) = \frac{1}{4p} \frac{1-g^2}{\left(1+g^2-2g\cos ?\right)^{3/2}} \qquad \text{where:} \qquad \int_0^p S(?) 2p \sin ? d? = 1$$

$$\int_0^p S(?) \cos ? 2p \sin ? d? = g$$

Monte Carlo Simulation

Monte Carlo simulation is a well established means of modeling the Boltzmann transport equation for photons in a scattering and absorbing medium. In this method, the path of each photon is simulated according to statistical parameters from the source to the detector. Based upon the properties of the scattering medium, the photon is moved a distance along its path. The photon's trajectory is then altered according to a distribution of scattering angles and it is moved again. This sequence repeats until the photon exits the scattering medium or is absorbed. The advantage of the Monte Carlo method is that it can be used to simulate arbitrarily complex geometries in absorbing and scattering mediums. However, this method does require substantial computational resources to simulate enough photons to have a statistically valid distribution.

The Monte Carlo method is widely used for simulating many types of problems that are difficult to model by other methods. Such problems include particle transport (for which the Monte Carlo method was originally developed) as well as finance, and statistics.

The essence of the Monte Carlo method is that an event which has a specified probability density function is represented by a random number with the same probability density function. When sufficiently large numbers of events are simulated in this manner, the distribution of probabilities that are randomly generated matches the specified distribution.

The Monte Carlo method is named for the manner in which the random numbers are generated – in essence the Monte Carlo method is a form of roulette strategy.

The Monte Carlo method is applied to photon transport in a homogenous medium as follows:

1. a photon is created with a specified location and trajectory
2. the photon is moved along its trajectory a random distance based upon the properties of the medium (absorption and scattering coefficients)
3. the photon trajectory is randomly changed
4. step 2 is repeated until the photon exits the scattering medium or is absorbed
5. properties of the photon are recorded
6. step 1 is repeated until a sufficient number of photons have been simulated
7. recorded results (distributions of photon properties) are post-processed and analyzed

Figure 1 shows a single photon making a "random walk" as it is modeled by the Monte Carlo method.

The random walk observed in Figure 1 represents the simulated path of the photon through the medium. When many photons are simulated in the same manner, the cumulative results approaches that of experimentally observed photon distributions.

The length of each leg that the photon travels between scattering events is determined by the scattering coefficient μ_s.

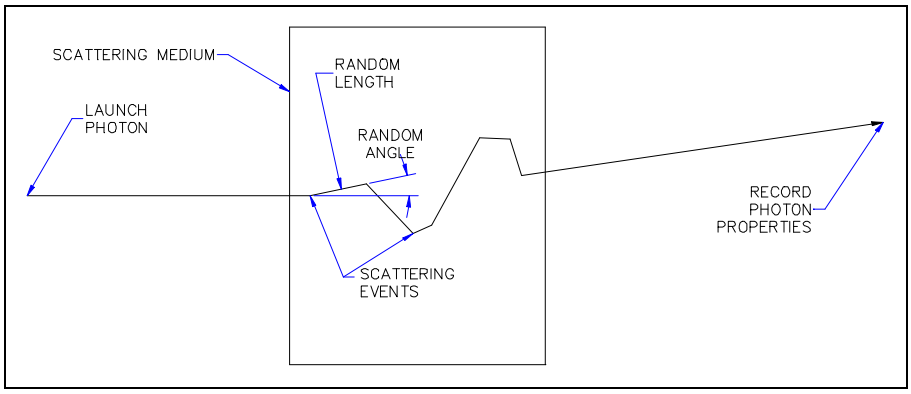


Figure 1 – Random Walk of Single Photon

The probability density function for the pathlength l_s, derived from the Beer-Lambert Law, is

$$p(l_s) = e^{-\mu_s l_s}$$

where:

$p(l_s)$ = probability that length l_s occurs such that $0 < p(l_s) < 1$

l_s = length of single leg of random walk between scattering events

From the probability density function, the random variable l_s can be directly determined

$$l_s = -\frac{\ln(p(l_s))}{\mu_s} = -\frac{\ln(RND)}{\mu_s}$$

where:

RND = random number uniformly distributed between 0 and 1 such that $0 < RND < 1$

A similar derivation can be used to determine the length of each leg l_a between absorption events based upon the absorption coefficient u_a.

The change in photon trajectory from O' *to* O at each scattering event is calculated by decomposing the trajectory into two components relative to the original trajectory, *?* and f, as shown in Figure 2.

The probability density functions for angles *?* and f are

$$p(f) = \frac{1}{2p}$$

$$p(q) = S(q)$$

where:

$p(f)$ = probability that angle f occurs such that $0 < \mathbf{p}(f) < 1$

$p(q)$ = probability that angle *?* occurs such that $0 < \mathbf{p}(?) < 1$ (this is the Henyey-Greenstein function)

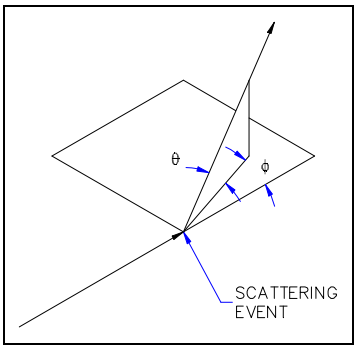


Figure 2 – Change in Photon Trajectory

From the probability density functions, the random variables $?$ and f can be directly determined

$$j = 2pRND$$

$$\cos(q) = \frac{1}{2g}\left[1 + g^2 - \left(\frac{1-g^2}{1-g+2gRND}\right)^2\right]$$

It can be seen that the sampling of distributions by random variables is at the core of all Monte Carlo simulations.

Optical Tomography

The foundation of optical tomography is the shadowgram, a two dimensional image that shows the differences in absorption of ballistic particles traveling through a medium. Figure 3 shows the primary components of an apparatus to produce shadowgrams.

In Figure 3, a photon source produces photons with trajectories that are perpendicular to the scattering medium. The photons enter the scattering medium and become one of the following types: highly scattered (strongly scattered back towards the photon source or away from the detector), scattered (reach the detector, but do not carry information about the internal structure of the scattering medium), quasi-ballistic (slightly scattered, but remain on a trajectory very close to the original trajectory), ballistic (no scattering occurs, the photons pass through directly the medium on a ballistic trajectory), blocked (path is blocked by the object), or absorbed (photon is absorbed by the medium).

In a perfectly non-absorbing and non-scattering medium with no reflection or refraction at the surface and a perfectly absorbing object within the medium, the photon detector would register only the ballistic photons and these photons would have a distribution equal to the source distribution in areas of the detector that are not shadowed by the object. There would be no photons within the shadow of the object on the detector. The accuracy of all optical methods of detecting photons to produce shadowgrams can be compared against this ideal model.

However, in a medium that is both scattering and absorbing, the photons exiting the medium do not have the same distribution as the source. As the scattering level is increased, the fraction of ballistic photons decreases. At scattering levels needed for biomedical applications, the relative fraction of ballistic photons is less than 10^{-8}. The challenge in optical tomography is to accept the photons that carry information about the internal structure of the scattering medium while rejecting those that do not.

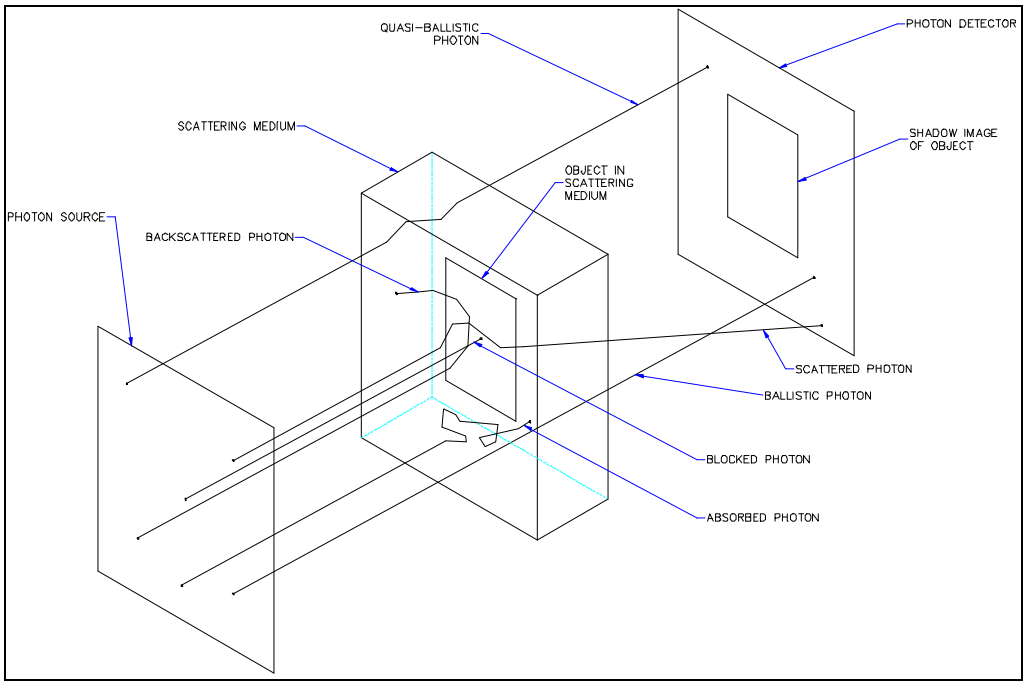


Figure 3 – Basic Setup for Producing A Shadowgram

In Figure 3, two types of photons carry information about objects within the medium: ballistic and quasi-ballistic photons. Ballistic photons have a pathlength (which can be directly related to travel time) through the medium that is equal to that of the medium and a trajectory that is unchanged by passage through the scattering medium. Quasi-ballistic photons have undergone one or more scattering events, but have been scattered in such a manner as to have pathlengths that are close to that of the medium and a trajectory that is only slightly changed by passage through the scattering medium. Clearly, the definition of what constitutes a quasi-ballistic photon is application dependent. For the purposes of this discussion, a quasi-ballistic photon is defined as a photon that carries information about objects within the medium such that if it is blocked by the object, the object's shadow will projected on a shadowgram with some specified degree of accuracy.

The problem of detecting objects using quasi-ballistic photons (sometimes referred to in the literature as snake photons) is made easier by the fact that, for many biological tissues, the phase function $S(?)$ is highly peaked towards scattering photons in a forward direction and the absorption coefficient μ_a is low for photons with infra-red wavelengths. This results in a relatively large number of quasi-ballistic photons available for use.

The photon detector shown in Figure 3 is used to create a photon density map. This is a map of photon quantities binned in a specific manner. Each time a photon passes through the detector, the quantity of a specific bin is incremented. Many different types of photon properties may be used to define the bins. If the bins are defined based on the x,y coordinates of the photon as it passes through the detector, then a 2D intensity image is formed. However, if the bins are defined using the trajectory of the photon (angular deviation from original trajectory) and the radial position of the photon (distance perpendicular to original trajectory from source), then a density map of trajectory vs. radial position is formed. Many different types of photon density maps may be defined and multiple photon density maps may be created.

Program Operation

The PTS software uses a command line interface to specify input and output files. A command line interface was chosen along with file-based I/O in order to allow the PTS software to operate on a wide variety of platforms, from PC's to multi-processor supercomputers.

The following sections described the command line interface, the input file syntax and the form of the output file containing the simulation results.

Command Line

The current program *m1main12.exe* is started by entering the program name and optional arguments on the command line of an MSDOS window. The form of the command is:

```
mmain12 [inputfilename] [outputfilename]
```

If the input file name is not specified, an input file name of *default.mci* is assumed. If the input file name does not contain an extension, then the extension *.mci* (Monte Carlo input) is assumed. If the output file name is not specified, then the output file name is assumed to be *inputfilenameroot.mco* where the root of the input file name is the input file name without the extension. The current directory is assumed unless the input file name path is specified. Some examples are shown in Table 1.

Table 1 –Examples of Parsing Input and Output File Names from Command Line

Command	Input File Name	Output File Name
`m1main12`	default.mci	default.mco
`m1main12 test1`	test1.mci	test1.mco
`m1main12 test1.txt`	test1.txt	test1.mco
`m1main12 test1a.in test1a.out`	test1a.in	test1a.out

Text Input File (.mci)

The input file contains a complete description of the simulation model and is processed by the PTS software prior to the commencement of a simulation run. Each simulation run requires a separate input file (batch runs are not supported by the current version of the PTS software).

The input file is written in a human readable, ASCII text form. It follows many standard ANSI C conventions such as the facility to include other input files using the #include statement, the ability to add comments using a leading "//" and the capability to split long lines using the line continuation character "\".

The level of complexity required to described the simulation model is not high, therefore a simple, context-based language was developed that mirrors the underlying object-oriented nature of the software. This language is used in both the input file and the output file, and indeed an output file may be read as an input file to recreate a simulation run. In this language, tokens (characters separated by white space or enclosed in quotation marks) are used as the fundamental syntactical building block. A token is evaluated in one of three ways: it is used to change the primary context, it is used to change the secondary context, or it is used to form a value based upon its position in a line (i.e. second token in the line, third token, etc.) and the current primary and secondary syntax.

An example of this input syntax is shown in the input file fragment below describing a photon source.

```
PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 100000000 //number of photons to launch from source
```

In the definition of the photon source, the first line *PhotonSource* is a primary context and causes a new photon source to be created. All subsequent tokens are evaluated assuming that they apply to this new photon source. The second line *id* token is a secondary context and causes subsequent tokens to be evaluated in the context of an identifier for the photon source. The token *"uniform source 1"* in the second line becomes the identifier for the photon source. The token *type* in the third line changes the secondary context from *id* to *type* and the token *UNIFORM* is evaluated as the type of the photon source. The token *p0* in the fourth line changes the secondary context to be that of point *p0* of the geometry associated with the photon source. The subsequent tokens *0*, *0*, and *0* on the fourth line are evaluated as the *x*, *y*, and *z* coordinates of point *p0*. The remainder of the photon source definition is evaluated in a like manner. The use of comments (indicated by the leading "//") greatly enhances the readability of the input file.

The types of primary and secondary contexts and the objects to which they apply are described in the following sections. Detailed examples of input and output files are given in the section *Test Cases*.

Information on a Simulation Run

The *RunInfo* primary context is used to define comments to describe a simulation run. Up to four lines of comments are allowed and the preferred form is shown in the example below:

```
RunInfo
  comment "Test Case xx"
  \       "Duplication of Chu and Pfeiffer Simulation Results"
  \       "to determine ratio of quasi-Ballistic to ballistic photons"
  \       "using a 1 cm thick scattering medium "
```

The line continuation character "\" is used to create four tokens on the same line as the *comment* token. Alternatively, each comment line may be specified individually preceded by a *commentn* token.

```
RunInfo
  comment0 "Test Case xx"
  comment1 "Duplication of Chu and Pfeiffer Simulation Results"
  comment2 "to determine ratio of quasi-Ballistic to ballistic photons"
  comment3 "using a 1 cm thick scattering medium "
```

Random Number Generator

Two types of random number generators are currently supported:

- Mersenne Twister (MT19937) pseudorandom number generator with period $2^{19937-1}$ by Takuji Nishimura and Makoto Matsumoto
- pseudorandom number generator (MC) used in program *mc2.c* by S. Jacques

Changing the type of random number generator is useful for cross-checking simulation results if there exists the possibility that the results were influenced by the sequence of pseudorandom numbers.

The random number generator may have two types: *MT* for Mersenne Twister and *MC* for Monte Carlo (used by Jacques). The initial seed used by the generator may be specified. The random number generator must be defined prior to a simulation run.

An example input file specification for the random number generator (defined using the *RandomNumberGenerator* primary context) is shown below.

```
RandomNumberGenerator //define the random number generator used for the simulation
  type MC //type of random number generator
  seed 0 //initial seed
```

Scattering and Absorbing Mediums

Three types of objects are supported by the PTS software: scattering and absorbing mediums, photon sources, and photon density maps. The geometry definitions used for all of these objects are the same and will be described in this section only.

A medium is a general purpose object that is used to represent real (i.e. physical) objects. Multiple mediums are allowed. A medium has a physical structure (position, orientation, and geometrical shape) and optical properties (absorption and scattering coefficients, index of refraction, and anisotropy factor *g*). A sample medium, defined using the *Medium* primary context, is shown below.

```
Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 .010001 //x, y, z coords of first point
  p1 1 -1 .010001 //x, y, z coords of second point
  p2 1 1 .010001 //x, y, z coords of third point
  p3 -1 1 .010001 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box
```

The *id* token is used to assign an identifier to the medium object (it is good practice to identify all objects). The anisotropy factor *g* is specified by the *g* token. It may have a value from –1 to 1, with 1 indicating that photons are scattered fully in the direction of their travel.

The *scatterratio* and *absorbratio* secondary context tokens are used to define the coefficient of scattering or absorption respectively. These ratios represent the predicted number of photons scattered or absorbed in transiting through the medium (along the extrusion path of the medium) to those that are not scattered or absorbed. For example, a *scatterratio* of 9 would indicate that 9 photons are scattered for each unscattered photon, or the probability of scattering in distance l_s is 90%. The relationship between *absorbratio* and coefficient of absorption μ_a is shown below. A similar relationship holds for scattering.

$$\mathrm{p}(l_a) = \frac{absorbratio}{absorbratio + 1}$$

$$\mu_a = -\frac{\ln(\mathrm{p}(l_a))}{l_a}$$

where:

p(l_a) = the probability that the photon will be absorbed in distance l_a

l_a = the extrusion length of the medium

The coefficient of scattering or absorption may also be specified directly

```
mus 0.000000 //coefficient of scattering (m^-1)
mua 2993.329531 //coefficient of absorption (m^-1)
```

The *indexrefraction* secondary context token is used to specify the index of refraction of the medium. If no index of refraction is specified, an index of refraction of 1 is assumed. Similarly, if no scattering or absorption coefficient is specified (either directly or indirectly), a value of zero is assumed.

The geometry of an object is fully defined by its shape. An identical shape definition method with the same secondary context tokens is used for photon sources and photon density maps as well as mediums. A shape definition consists of a shape type (*RECTANGLE*, *CIRCLE*, or *SEMISHERE*), several defining points, an optional normal vector, and an optional extrusion length. All distances, coordinates, lengths, etc. are defined in meters.

Two-Dimensional Primitive Shapes

A rectangular shape is defined by four co-planar points p_0, p_1, p_2, and p_3 representing the corners of the rectangle. The surface normal to this rectangle may be specified by the *normalvector* value token or is calculated by taking the cross product of the vector from p_0 to p_1 with the vector from p_0 to p_2. Points are defined by the secondary context token p_0, .., p_3 followed by three values representing the *x*, *y*, and *z* absolute coordinates of the point. In the sample medium defined above, point p_0 is (-1, -1, 0.010001).

A circle shape is defined by two or three co-planar points p_0, p_1, and optionally p_2. Point p_0 is the center of the circle and point p_1 is a point on the circumference of the circle. If the surface normal vector is specified using the *normalvector* token, then no additional points are required. If the surface normal vector is not specified, then point p_2 lying on the circumference of the circle and not co-located with point p_1 is needed so that the surface normal vector may be calculated by taking the cross product of the vector from p_0 to p_1 with the vector from p_0 to p_2.

Three-Dimensional Primitive Shapes

A semi-sphere shape (a portion of a sphere with a flat edge) is defined by two or three co-planar points p_0, p_1, and optionally p_2 in the same manner as a circle. Point p_0 is the center of the sphere and point p_1 is a point on the circumference of the sphere. If the surface normal vector to the great circle formed by p_0 and p_1 is specified using the *normalvector* token, then point p_2 is not required. If the surface normal vector is not specified, then point p_2 lying on the circumference of the sphere, co-planar with p_0 and p_1, and not co-located with point p_1 is needed so that the surface normal vector of the great circle formed by points p_0, p_1, and p_2 may be calculated by taking the cross product of the vector from p_0 to p_1 with the vector from p_0 to p_2. A cutting plane that is perpendicular to the normal vector is defined by point p_3 which lies on the cutting plane. The portion of the sphere defined by the above points and bisected by the cutting plane that is considered to be the shape of the medium is the portion that has the normal vector passing from inside the medium to outside the medium through the cutting plane as shown in Figure 4.

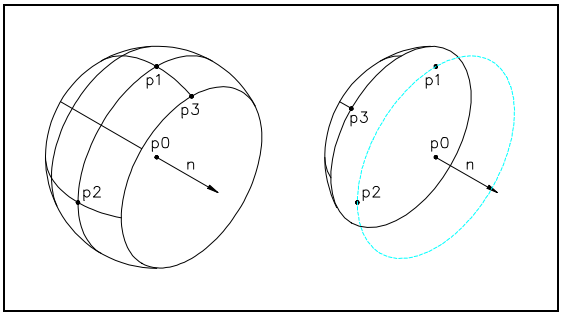


Figure 4 – Defining a Semi-Sphere

All mediums must be three-dimensional objects (not planar). This implies that a positive, non-zero extrusion length must be specified for *RECTANGLES* and *CIRCLES* (plane shapes otherwise). A *SEMISPHERE* is a three-dimensional dimensional object and the extrusion length is not used.

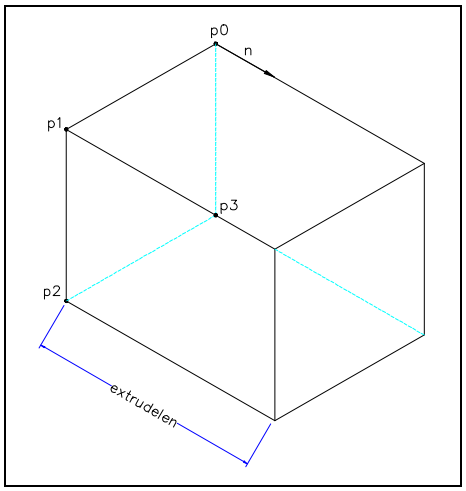


Figure 5 – Defining A Cube

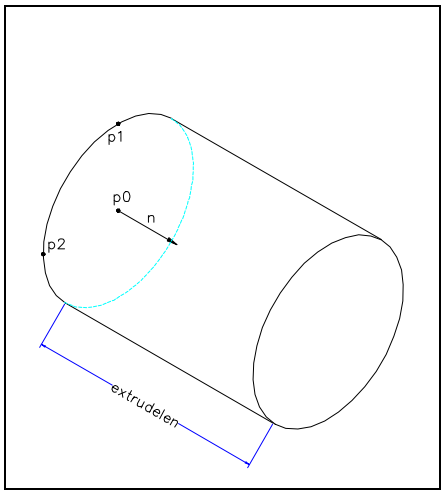


Figure 6 – Defining a Cylinder

An extruded plane rectangle forms a cube and an extruded plane circle forms a cylinder as shown in Figures 5 and 6. The extrusion is performed in the direction of the surface normal vector to the plane and is of the length specified by the *extrudelen* value token. It should be noted that surface normals, as defined by the PTS software, always point into a 3D object.

NURB Primitive Shapes

NURB surfaces are parametric surfaces that represent arbitrary surfaces in space. In essence, a NURB surface is a mapping from *u*, *v* parameter space to *x*, *y*, *z* ($\mathbf{R}^3$) space. A description of NURB surfaces is beyond the scope of this User Manual, please see *Development of NURB Surface and Visualization Extensions to the Photon Transport Simulator* for details.

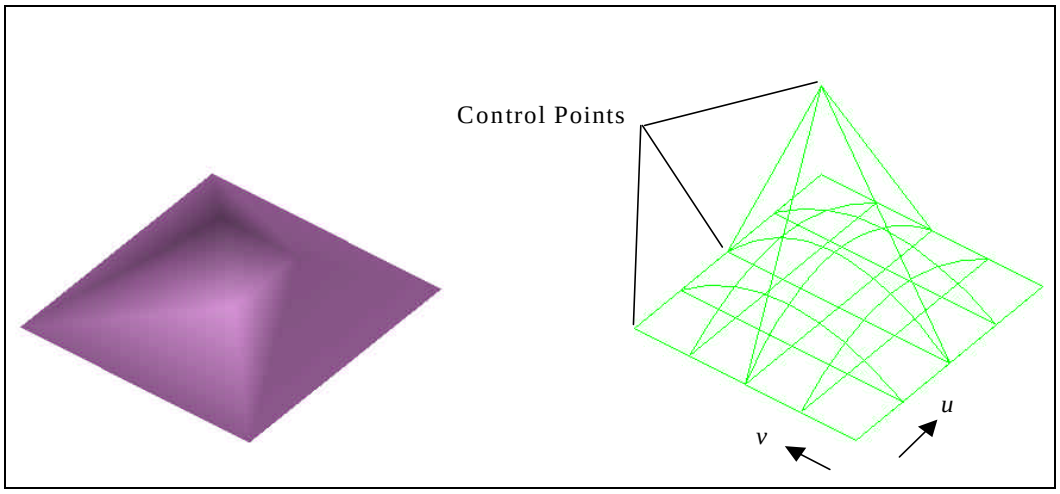


Figure 7 – Rendered and Wireframe View of Simple NURB Surface

Control points $\mathbf{P}_{i,j}$ form a net within which the NURB surface lies (the surface lies within the convex hull of the control points). The number and location of knots and the degree may be different for the *u* and *v* directions. For the NURB curve and surface software extensions developed for the PTS system, the parameters are assumed to lie between 0 and 1, with the endpoints representing the endpoints of open, non-singular NURB curves and surfaces.

The simple NURB surface of degree 2 in both the *u* and *v* directions is shown in Figure 7.

The PTS software is primarily intended for photon transport simulation of scattering mediums and needs to be able to represent rather simple objects. The rationale for developing NURB surface extensions was to be able to accurately model non-spherical optical lenses and mirrors as well as "soft objects". Due to the limitations of the underlying geometry data structure already in place, a subset of full NURB surfaces was developed.

A NURBPLANE shape is defined as the three-dimensional shape formed by the intersection of a NURB surface and a plane. This shape is sufficient within the context of the PTS system to represent a wide range of lens and mirror geometries. Double sided NURB surfaces may be formed by combining two NURBPLANE objects in such a manner as to align their planes.

The syntax for a NURBPLANE shape is described below.

shptype	NURBPLANE
p0	point through which cutting plane passes (cutting plane is perpendicular to reference vector and intersects the NURB surface)
refvector	a normal vector to the cutting plane, the NURB surface in the direction of this vector is kept, the NURB surface in the direction opposite to this vector is discarded
controlpointsu	number of control points in the *u* direction
controlpointsv	number of control points in the *v* direction
degreeu	degree of curve in *u* direction (between knots)
degreev	degree of curve in *v* direction (between knots)
knotu	knot for *u* direction (multiple knots may be listed on a single line)
knotv	knot for *v* direction (multiple knots may be listed on a single line)
knotsu	number of knots in *u* direction (optional, if omitted is determined by the number of knots in the knot vector)
knotsv	number of knots in *v* direction (optional, if omitted is determined by the number of knots in the knot vector)
controlpoint	an individual control point of the form *x*, *y*, *z*, *w* (multiple control points may be listed on a single line)

A NURBPLANE shape is defined in a manner similar to other mediums. An example of a medium with a NURBPLANE shape that incorporates the NURB surface shown in Figure 7 is shown in the input file fragment below.

```
Medium
  id "nurb plane 1" //sample of test nurb plane
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 2 //index of refraction
  shptype NURBPLANE //shape of medium
  p0 0.0000000 0.0000000 0  //point on plane (the cutting plane passes through this point)
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal for plane
  controlpointsu 3 //the number of control points in the u direction
  controlpointsv 3 //the number of control points in the v direction
  degreeu 2 //the degree of the curve in the u direction
  degreev 2 //the degree of the curve in the v direction
  knotu 0 0 0 1 1 1 //the knot vector for the u direction
  knotv 0 0 0 1 1 1 //the knot vector for the v direction
  controlpoint -0.5 -0.5  0.0  1.0 //the first control point P(i=0,j=0)
  controlpoint  0.0 -0.5  0.0  1.0 //the second control point P(i=1, j=0)
  controlpoint  0.5 -0.5  0.0  1.0 //the third control point P(i=2, j=0)
  controlpoint -0.5  0.0  0.0  1.0 //P(i=0, j=1)
  controlpoint  0.0  0.0  1.0  1.0 //P(i=1, j=1) note that the z coordinate is non-zero
```

```
  controlpoint  0.5  0.0  0.0  1.0 //P(i=2, j=1)
  controlpoint -0.5  0.5  0.0  1.0 //P(i=0, j=2)
  controlpoint  0.0  0.5  0.0  1.0 //P(i=1, j=2)
  controlpoint  0.5  0.5  0.0  1.0 //the last control point P(i=2, j=2)
```

Complex Shapes

Scattering and absorbing medium objects defined by the input file may intersect. In this case, the medium within which a point is considered to lie is medium which was defined last. This characteristic of the PTS software allows complex assemblies of objects to be constructed from simple shapes and mediums. Three examples are given: a collimating hole within an absorbing medium, a diverging lens, and a bounding box.

A collimating hole is constructed by first defining a cube of absorbing medium that is the thickness of the collimator. The absorption ratio should be set high enough that no photons will pass through the medium without being absorbed. The collimating hole is added by defining a cylinder with the optical properties of air (or vacuum) *after* the absorbing medium has been defined. Any photons located within the cylinder will use the optical properties of the cylinder (air) and not those of the absorbing medium. If internal reflections are not permitted, then the index of refraction of the absorbing medium should be made equal to that of the cylinder. This assembly will act as a collimating hole, absorbing all photons whose trajectories are not closely aligned with the hole. A sample definition of such an assembly is shown below.

```
Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.261 //x, y, z coords of first point
  p1 1 -1 10.261 //x, y, z coords of second point
  p2 1 1 10.261 //x, y, z coords of third point
  p3 -1 1 10.261 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator hole medium" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole
```

As the purpose of the PTS software is to enable the use of lens systems to be investigated as a means of enhancing the filtering properties of collimator arrays in angular domain imaging systems, it was decided that the ability to model lenses accurately was required. Initially, thin lenses were to be modeled as discrete planar objects which altered the trajectory of photons passing through them. However, the addition of Fresnel reflection and refraction at the surface of mediums provided a better mechanism for simulating lenses. The semi-sphere shape was described earlier and was implemented to allow simple lens systems to be modeled. A lens is constructed of one or more mediums with the desired shape. This shape is a function of the desired optical properties and is used in conjunction with the index of refraction to determine the lens characteristics. At present, there is no facility for defining lenses using magnification ratios or focal distances, rather the reader is referred to basic optics texts for the relevant formulas. However, once the shape of the lens is determined, it can be specified through the use of medium objects and the optical characteristics of the lens will be faithfully modeled by the PTS software.

A diverging lens is the first element of a Gaussian beam expander and may also be used in beam shrinkers. A plano diverging lens is modeled by superimposing a semi-sphere of air on a cube of glass. A sample definition of a diverging lens with a focal distance of –25 mm (used as the first element of a 10 x Gaussian beam expander) is shown below. The complete beam expander, of which this lens is a part, is described in section *Test Case 5*.

```
Medium //define a scattering and absorbing medium
  id "diverging lens 1" //glass part of diverging lens
```

```
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1.45 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10 //x, y, z coords of first point
  p1 0 0.015 10 //x, y, z coords of second point
  normalvector 0 0 1 //normal vector for extrude
  extrudelen  0.004 //extrusion length of cylinder

Medium //define a scattering and absorbing medium (lens semi-sphere shape)
  id "diverging lens 2" //air part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 10.012 //x, y, z coords of first point
  p1 0 0.01125 10.012 //x, y, z coords of second point
  p3 0 0 10.004 //x, y, z coords of fourth point
  normalvector 0 0 1 //normal vector of cut surface (plano side on right)
```

Boundary and Ambient Media

A bounding box is a cube that encompasses the entire model "space". Its purpose is to absorb all photons that reach its inner surface. The PTS software requires that a bounding box be specified. A bounding box is used in conjunction with an ambient medium to provide a "universe" within which the simulation model exists. The bounding box is the first medium defined in the input file and extends beyond the entire model. A bounding box of length, width and height of 2002 meters, centered on (0,0,0) is used for all test cases described. The ambient medium specifies the properties used whenever the photon does not lie within a user-specified medium object. The ambient medium (usually defined to have the properties of air or vacuum) is the second medium defined in the input file and is superimposed on the bounding box. An ambient medium of length, width and height of 2000 meters, centered on (0,0,0) is used for all test cases described. This combination of ambient medium and bounding box gives a simulation space from (-1000, -1000, -1000) to (+1000, +1000, +1000). Any photons that travel through the ambient medium without reaching a user-defined medium encounter the bounding box and are absorbed. A definition of bounding box and ambient medium used for all of the test cases is shown below.

```
Medium //define a scattering and absorbing medium
  id "bounding box medium 0"
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 100000000.0 //coefficient of absorption
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1001 -1001 -1001 //x, y, z coords of first point
  p1 1001 -1001 -1001 //x, y, z coords of second point
  p2 1001 1001 -1001 //x, y, z coords of third point
  p3 -1001 1001 -1001 //x, y, z coords of fourth point
  extrudelen 2002 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "test medium 0 (ambient)"
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1000 -1000 -1000 //x, y, z coords of first point
  p1 1000 -1000 -1000 //x, y, z coords of second point
  p2 1000 1000 -1000 //x, y, z coords of third point
  p3 -1000 1000 -1000 //x, y, z coords of fourth point
  extrudelen 2000 //extrusion length of box
```

In summary, a medium object is used by the PTS software as a flexible mechanism for representing physical objects of arbitrary shapes. The combination of the absorption, scattering, reflection, and refraction properties of mediums allows not only scattering objects to be simulated but also embedded objects, collimating holes, lenses, bounding boxes, shadow masks, and more.

Photon Sources

A photon source is a source of photons used in the simulation. Multiple photon sources are allowed. A photon source has a physical structure (position, orientation, and geometrical shape), a distribution of photons, and a quantity of photons to launch. In addition, the wavelength of photons may be specified, although wavelength dependent behaviour is not supported by the PTS software at this time.

A sample photon source, defined using the *PhotonSource* primary context, is shown below.

```
PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in cm
  p1 0 0.00125 0 //x, y, z coords of point on circumference in cm
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1000000 //number of photons to launch from source
```

The initial trajectory of all photons is that of the unit normal vector of the photon source shape unless a spherical or HG angular distribution is specified, in which case the distribution is centered on the unit normal vector of the photon source shape.

Table 2 shows the seven types of photon sources that are implemented.

Table 2 – Types of Photon Sources

Source Type	Source Description
POINT	photon source launches all photons from point p0
UNIFORM	photon sources launches photons from within the plane circle defined by the shape with a photon intensity distribution that is constant across the circle
GAUSSIAN	photon source launches photons with a photon intensity distribution that follows a Gaussian distribution centered on the plane circle with a spot size equal to the circle diameter
SPHERICAL	point source type with spherical distribution
POINTHG	point source type with Henyey-Greenstein distribution (specified by g)
POINTSPHERICALUZ	point source type with spherical distribution confined to a solid angle (specified by uz = + or - alpha around source reference vector)
UNIFORMSPHERICALUZ	uniform source type with spherical distribution confined to a solid angle (specified by uz = + or - cos alpha around source reference vector)

A sample photon source with uniform spherical distribution is shown below. This photon source is a planar disc of radius 200 microns emitting photons that are uniformly distributed over angles from ±0.81° of the photon source normal. The uz parameter of 0.9999 specifies the cosine of the limit angle for the uniform angular distribution. It is most useful for ensuring that photons are randomly emitted in the primary direction of interest.

```
PhotonSource //define a photon source
 id "Uniform spherical uz source 2 - on z-axis"
  type UNIFORMSPHERICALUZ //uniform spherical distribution confined to +- traj uz
  shptype CIRCLE //shape of source is a circle
  p0 0.000000 0.010000 0.000000 //x, y, z coords of center in m
  radius 0.000200 //radius of circular map
  normalvector 0 0 1 //launch photons parallel to z axis
  uz 0.9999 //max forward trajectory for uniformly distributed photon angles
  qty 1000000 //number of photons to launch from source
```

Photon Density Maps

A photon density map is a planar photon detector object that is used to capture information from photons as they pass through its surface. Multiple photon density maps are allowed. A photon density map has a physical structure (position, orientation, and geometrical shape), and a data table of photon information. At present, only rectangular and circular density maps are supported (2D only, not 3D).

A sample photon density map, defined using the *Map* primary context, is shown below.

```
Map //define a density map
  id "x-y pos of beam before expansion"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 9.9 //x, y, z coords of first point
  p1 -1  1 9.9 //x, y, z coords of second point
  p2 -1 -1 9.9 //x, y, z coords of third point
  p3  1 -1 9.9 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.002 +0.002 0.0001 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.002 +0.002 0.0001 //hash lookup, y pos
```

This photon density map is defined to be a plane rectangle of width and height equal to two meters centered on (0, 0, 9.9) lying parallel to the *x-y* plane. All photons that passes through this rectangle are evaluated according to photon calculations defined in the *idxcol* and *idxrow* token lines (idx is short for index). The photon calculations for each index *idxrow* and *idxcol* generate a table cell reference (equivalent to bin location) for the passing photon event and the value of that cell is incremented. In this manner, a two dimensional map of photon density information is compiled during the simulation run.

The tables used by photon density maps are arranged in rows and columns which define cells. A cell is a bin that extends between a minimum and maximum row index value and a minimum and maximum column index value. Index structures for the rows and columns are used to map the floating point values produced by the photon calculations to a particular cell.

An index structure is defined by the *idxcol* or *idxrow* token line. This line has the form

```
idxcol id hash photoncalculationtype valmin valmax valdelta
```

where *id* is the identifier of the index, "hash" is the only lookup type presently implemented, *photoncalculationtype* is the type of photon calculation for the index, *valmin*, *valmax*, and *valdelta* are the minimum, maximum, and delta values for column index bins.

In the map above, the column index is defined by the *idxcol* token line to be a hash lookup function with a minimum column index value of –0.0020 m, a maximum column index value of +0.0020 m, and a column bin width of 0.0001 m. This forms a column index with values -0.0020, -0.0019, -0.0018, ..., +0.0018, +0.0019, +0.0020. There are 41 columns in this index with the first column consisting of values from -0.0020 up to, but not including -0.0019 and the last column consisting of values from +0.0020 up to, but not including +0.0021.

The *photoncalculationtype* token specifies what information is extracted from the passing photon. Using the rows and columns of a single table, two items of photon information may be correlated by each photon density map. In the map above, the *PHOTPOSX* and *PHOTPOSY* tokens specify that the *x* coordinate and the *y* coordinate (absolute) of the photon position as it passes through the density map are used to create the density map. This results in an image of the photon flow with the intensity of the image being relative to the number of photons passing through a particular bin. Figure 10 in section *Test Case 1* shows the image produced by such an density map.

A number of types of photon calculations are defined. It is expected that additional calculation types will be added as the PTS software is expanded. Each type of photon calculation returns a single floating point number, with the exception of PHOTINFO which not only returns a value equal to the number of time the photon has move, but also causes a summary of the information for each photon that triggers the PHOTINFO calculation to be printed in the output file. Table 3 shows the allowable types of photon calculations.

Table 3 – Types of Pre-defined Photon Calculations

Calculation Type	Calculation Description
PHOTPOSX	X component of current position (m)
PHOTPOSY	Y component of current position (m)
PHOTPOSZ	Z component of current position (m)
PHOTPOSXSOURCE	X component of current position (reference to the photon source)
PHOTPOSYSOURCE	Y component of current position (reference to the photon source)
PHOTPOSZSOURCE	z component of current position (reference to the photon source)
PHOTPOSRSOURCE	radial component of current position (reference to the photon source normal)
PHOTPOSRMAXSOURCE	maximum radial component of any recorded position (reference to the photon source normal)
PHOTPOSXSTART	x component of current position (reference to the photon start pos)
PHOTPOSYSTART	y component of current position (reference to the photon start pos)
PHOTPOSZSTART	z component of current position (reference to the photon start pos)
PHOTPOSRSTART	radial component of current position (reference to the photon start trajectory and pos)
PHOTPOSRMAXSTART	maximum radial component of any recorded position (reference to the photon start trajectory and pos)
PHOTTRAJX	x component of current trajectory
PHOTTRAJY	y component of current trajectory
PHOTTRAJZ	z component of current trajectory
PHOTTRAJDOTSOURCE	dot product of current trajectory and photon source (cosine of forward scattering angle for photons with starting trajectory equal to source normal)
PHOTTRAJDOTSTART	dot product of current trajectory and photon starting trajectory (cosine of forward scattering angle)
PHOTMOVECOUNT	Number of times that photon is moved
PHOTSCATTERCOUNT	Number of scattering events
PHOTREFLECTCOUNT	Number of reflect events
PHOTREFRACTCOUNT	Number of refract events
PHOTWAVELENGTH	Wavelength (nm)
PHOTPATHLENGTH	pathlength (m)
PHOTLIFE	life (seconds)
PHOTINFO	prints photon information (including position list) to outfile, but returns the number of photon moves (movecount)
PHOTPOSRMAXSOURCE	maximum radial component of any recorded position (reference to the photon source normal)
PHOTPOSRSTART	radial component of current position (reference to the photon start trajectory and pos)
PHOTPOSXSTART	x component of current position (reference to the photon start pos)
PHOTPOSYSTART	y component of current position (reference to the photon start pos)
PHOTPOSZSTART	z component of current position (reference to the photon start pos)
PHOTPOSRMAXSTART	maximum radial component of any recorded position (reference to the photon start trajectory and pos)

Table 3 – Types of Pre-defined Photon Calculations cont.

Calculation Type	Calculation Description
PHOTPATHLENGTHFRAC	fraction formed by dividing pathlength by distance from photon launch to current position
PHOTQTYCOUNT	photon id (quantity count of photons so far)
PHOTTRAJSTARTDOTSOURCE	starting trajectory wrt source
PHOTPOSRSTARTSOURCE	starting radial position wrt source
PHOTTRAJDEVMAX	dot product of maximum trajectory deviation and photon source (trajectory deviation for each photon location is the angle from the current location to the historical location wrt source trajectory)

If PHOTINFO is used to define one of the photon calculations in a density map, then each photon that passes through the map will cause the photon's trajectory history (point by point) to be written to the output file. This is useful for visualizing photon distributions and paths. However, as the file size can quickly become very large, some care should be taken in limiting the number of photons passing through the map.

A sample of the photon information in the output file produced by the PHOTINFO calculation is shown below.

```
PhotonInfo //photon information
  posstart 0.000000 0.000002 0.000000  //starting position
  trajstart 0.000000 0.000000 1.000000  //starting trajectory
  poscurrent 0.000005 0.000023 10.271001  //current position
  trajcurrent 0.000000 0.000000 1.000000  //current trajectory
  medium test medium 0 (ambient) //current medium in which photon resides
  wavelength 514.000000 //wavelength of photon (nm)
  movecount 10 //number of moves made by photon
  scattercount 0 //number of scatter events
  reflectcount 0 //number of reflect events
  refractcount 10 //number of refract events
  pathlength 10.271001 //total pathlength (m)
  life 0.000000034277 //lifetime of photon (secs)
  desireddist 10000000000000000000.000000 //current desired distance
  photposrsource 0.000024 //radial component of current position (wrt to the photon source normal)
  photposrstart 0.000021 //radial component of current pos (wrt to the photon start traj and pos)
  phottrajdotsource 1.000000 //dot product of current traj and photon source (cos of fwd sct angle)
  phottrajdotstart 1.000000 //dot product of current trajectory and photon starting traj
  photposrmaxsource 0.000024 //max radial component of any recorded pos (wrt the phot source normal)
  photposrmaxstart 0.000021 //max rad component of any recorded pos (wrt the phot start traj and pos)
  poslist 0.000000 0.000002 0.000000  //starting position
  \       0.000000 0.000002 10.000000
  \       0.000000 0.000002 10.000750
  \       0.000001 0.000003 10.004000
  \       0.000005 0.000023 10.223500
  \       0.000005 0.000023 10.224000
  \       0.000005 0.000023 10.250000
  \       0.000005 0.000023 10.250500
  \       0.000005 0.000023 10.251000
  \       0.000005 0.000023 10.261000
  \       0.000005 0.000023 10.271000  //last recorded position
```

In order to extend the usefulness of photon density maps, three optional commands (secondary contexts) are defined. The *calccriteria* determines the eligibility of photons to be considered for calculations (adding to the binned density). The *absorbcriteria* determines under what conditions photons are absorbed by the density map and allows the density map to act as a perfect absorbing plane in some situations. The *containmax* command determines the maximum number of photons that the density map will contain (useful for limiting the number of photon trajectory histories recorded with the PHOTINFO command).

The *calccriteria* and *absorbcriteria* may have the following values:

NONE -	no photons meet criteria
NORMAL -	photons in normal direction meet criteria
ANTINORMAL -	photons in anti-normal direction meet criteria
ALL -	all photons meet criteria
CALC -	photons meet criteria if they meet calc limits for table
ANTICALC -	photons meet criteria if they do not meet calc limits for table

By default, *calccriteria* is defined as ALL, *absorbcriteria* is defined as NONE, and *containmax* is approximately infinite for a photon density map.

As a post-processing aid, a number of values are calculated (calccount, absorbcount, totalcount, containcount) and displayed as comments. An example output (excluding the data section) of a photon density map is shown below.

```
Map //define a photon density map
  id "image pixel map" //id of density map
  type PLANAR //type of density map
  calccriteria ALL //calculation criteria for density map
  absorbcriteria NONE //absorption criteria for density map
  //calccount 205653 //number of photons that met calccriteria
  //absorbcount 0 //number of photons that met absorbcriteria
  //totalcount 205653 //number of photons that passed through density map
  //containcount 87777 //number of photons contained within density map
  containmax 10000000000000000000 //max number of photons allowed to be contained within density map
  shptype CIRCLE //type of shape for object
  p0 0.00000000 0.00000000 0.08600000  //point 0 (center for circle)
  p1 0.00000000 0.00000000 0.00000000  //point 1
  p2 0.00000000 0.00000000 0.00000000  //point 2
  p3 0.00000000 0.00000000 0.00000000  //point 3
  normalvector 0.00000000 0.00000000 1.00000000  //surface normal
  extrudelen 0.00000000 //extrusion length (m) (0 if planar)
  radius 0.00500000 //radius of circle (m)
  radius2 0.0000250000 //radius of circle squared (m^2)
  idxrow "image y pos" HASH PHOTPOSY -0.00100000 0.00100000 0.00001000 //row index
  idxcol "image x pos" HASH PHOTPOSX -0.00100000 0.00100000 0.00001000 //column index
```

Text Output File (.mco)

The output file contains a complete description of the simulation model as well as the results produced by photon density maps and PHOTINFO calculations. The output file is in the same form (uses the same language and syntax) as the input file, allowing the output file to act as the input file to the PTS software if desired (useful for recreating simulation runs).

Any #include statements in the original input files are eliminated in the output file, rather the actual included text is printed at the location of the #include statement.

In the output file, additional information is added to the RunInfo primary context such as shown in the sample below.

```
RunInfo //information on this simulation run
  comment0 "Run to test basic photon transport, uniform photon source"
  comment1 "Test 10 x beam expander with slit"
  comment2 ""
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in
Media"
  programname " pts1.exe (m1main12.c)"
  programauthor "Nick Pfeiffer"
  programversiondate " February 2005"
  inputfile "default.mci" //name of input file for this run
  outputfile "default.mco" //name of output file for this run
  photonqty 1000000 //total number of photons in all sources
  runstart Sat Dec 21 17:00:42 2005//starting time and date of run
  runend Sat Dec 21 17:08:32 2005//ending time and date of run
```

The output file not only prints the definition of each object from the input file, it also provides some additional calculated values in the form of comments. Review of such calculated values (such as the radius of a circle or the normal vector of a shape) is useful for ensuring that the input model was properly specified. The output from a sample photon source is shown below.

```
PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 1000000 //initial number of photons in source to launch
  //qtyleft 1000000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
  p0 0.000000 0.000000 0.000000  //point 0 (center for circle)
  p1 0.000000 0.001250 0.000000  //point 1
  p2 0.000000 0.000000 0.000000  //point 2
  p3 0.000000 0.000000 0.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.001250 //radius of circle (m)
  //radius squared 0.000002 //radius of circle squared
```

The output from photon density maps include a data section (the secondary context *data* followed by a single line of token values (formatted as multiple lines through the use of the line continuation character "\") as shown in the small, sample map below. The row and column bin values are indicated by comments.

```
Map //define a photon density map
  id "x-y pos of beam upstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.000000 1.000000 0.010001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.010001  //point 1
  p2 -1.000000 -1.000000 0.010001  //point 2
  p3 1.000000 -1.000000 0.010001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000030 0.000024 0.000012 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000030 0.000024 0.000012 //column index
  //   -0.000030       -0.000018       -0.000006        0.000006        0.000018
  data      0.00          218.00          453.00          228.00            0.00  //-0.000030
  \       220.00          702.00          743.00          716.00          212.00  //-0.000018
  \       406.00          729.00          720.00          717.00          440.00  //-0.000006
  \       218.00          747.00          691.00          737.00          211.00  //0.000006
  \         0.00          229.00          428.00          235.00            0.00  //0.000018
```

The density map output is easily imported into a spreadsheet program by copying the data table to a text file and importing the text file with spaces specified as the token delimiters. Only minor editing of the table is required in order to allow numerical post-processing.

The PHOTINFO calculation, when triggered by a photon passing through a photon density map, causes a summary of the photon's current information to be printed. A sample of such a printout is shown in the section *Photon Density Map* above. Care should be taken with the number of photons producing this calculation or the output file can become large.

Scheme Output File (.scm)

The Scheme language output file contains a complete description of the geometry of the simulation model as well as specified photon trajectories. The Scheme language output file is intended to be processed by the Scheme language extensions of the ACIS solid modeler. Once the Scheme output file has been loaded by the ACIS Scheme extensions, the three-dimensional results may be viewed, scaled, rotated, and otherwise displayed. Several examples of ACIS 3D models produced by loading the Scheme file (with minor editing) are shown in Figure 8.

The PTS system builds complex objects from simple primitives such as blocks, cylinders, spheres, and simple forms of NURB surfaces. True solid models are not maintained by the PTS system, rather a method is employed whereby when primitives intersect, the primitive which was defined last occupies the

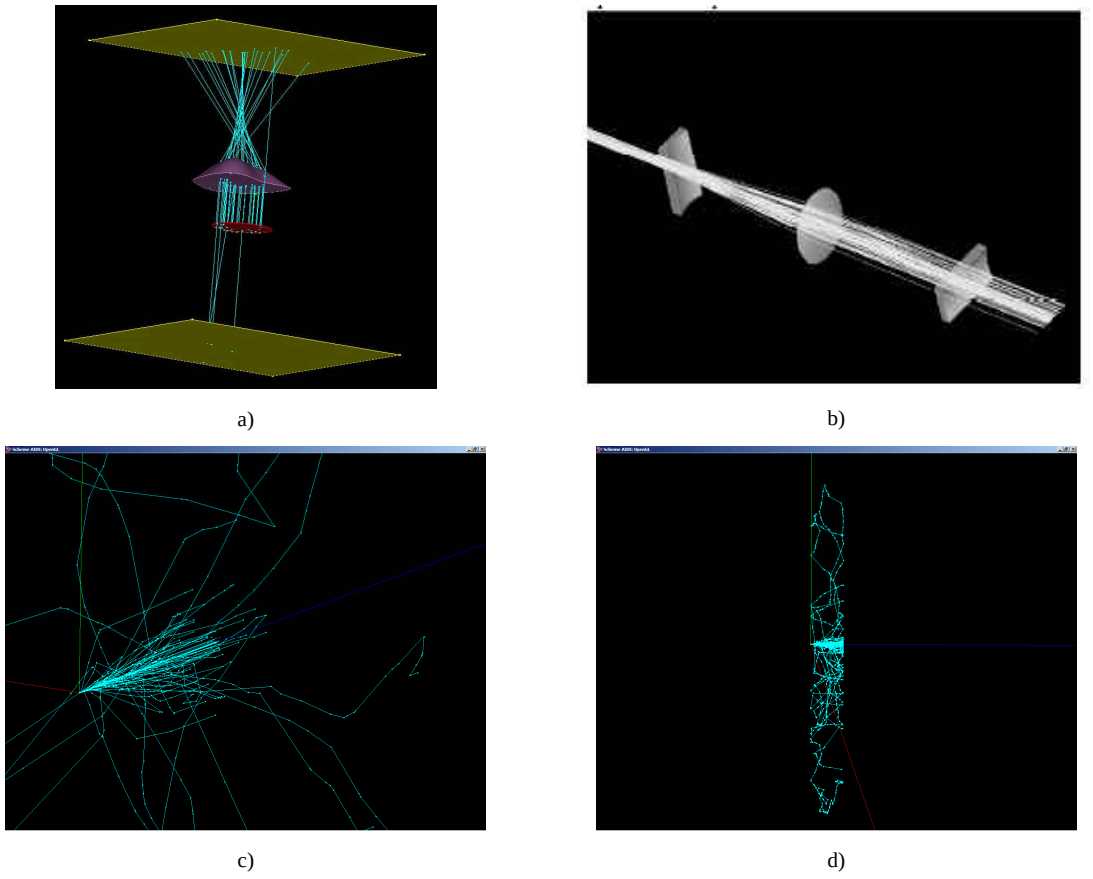
intersection volume. The Scheme output file contains ACIS Scheme descriptions of the primitives only, complex objects will appear as superimposed primitives.

When a photon strikes a photon density map which has PHOTINFO as one of the calculations, a list of all photon positions (trajectory history) is printed to the output file. At the same time, a Scheme description of the photon's trajectory is created as an ACIS wire body entity. When the Scheme file is loaded into ACIS, the trajectories of such photons may be viewed (viewing of edges and vertices should be enabled for the OpenGL window).

The Scheme output from a sample photon source is shown below.

```
(define uniform_source_1 (sheet:2d (sheet:face (face:planar-disk (position 0.000000 0.000000
0.000000) (gvector 0.000000 0.000000 1.000000) 0.001250)))) ;uniform_source_1 is a planar disk
```

It can be seen that the identifier assigned to the object in the input file is used (with spaces replaced by underscore characters) as the entity name in Scheme.



a) b) c) d)

Figure 8 – Examples of ACIS Solid Models: a)reflection/refraction from NURBPLANE with a uniform photon source, b) Cylindrical/Spherical/Cylindrical Beam Expander, c) scattering within a medium from a point photon source, d) side view of scattering within a medium from a point photon source

The current version of the PTS parser does only rudimentary checking (primarily syntax checking) on geometric data. It is quite possible to generate a non-manifold shape. The Scheme visualization output files for ACIS aid in detecting these errors after the fact, as non-manifold geometry can be viewed by the user.

The ACIS Scheme language translator exhibits occasional problems in loading Scheme output files. These errors are usually the result of a mismatch between the geometric tolerances used by the PTS software and those of the ACIS system. Such errors are caused by specifying points that are too close together in a wire body of a photon trajectory. Future work may be needed to identify the proper tolerances to use when translating geometries to Scheme.

The Scheme output of a photon trajectory is shown below. Comments are automatically created to aid Scheme program readability.

```
;create a wire body of photon trajectory for photon uniform_source_1_0
(define uniform_source_1_0
  (wire-body:points
    (list
      (position 0.3941447 -0.2066050 -0.5000000 ) ;movecount = 0
      (position 0.3941447 -0.2066050 0.0000000 ) ;movecount = 1
      (position 0.3941447 -0.2066050 0.0784892 ) ;movecount = 2
      (position 0.2069607 -0.1618084 0.0000000 ) ;movecount = 3
      (position -0.2430430 -0.0541142 0.1886936 ) ;movecount = 4
      (position -0.3026797 0.0130430 0.0000000 ) ;movecount = 5
      (position -1.5311961 1.3964815 -1.1000000 ) ;current position
    ) ;end position list
  ) ;end wire-body
) ;end define uniform_source_1_0
```

Test Cases

The preceding sections have introduced photon transport through Monte Carlo simulation and described the input and output file formats along with program operation. This section is dedicated to describing a number of test cases that showcase particular aspects of the PTS software. It is expected that the user will become acquainted with the definition of simulation models and the types of results possible by following these test cases.

Each test case is comprised of an input file with the *.mci* extension and an output file with the *.mco* extension. These files can be found in Appendices A to M. The majority of the test cases were run with a limited number of photons in order to demonstrate a particular principle. All test cases are capable of being re-run by the user with larger numbers of photons.

Test Case 1 – A Single Medium with No Scattering or Absorption

A simple test case is to duplicate some of the work of Jacques and Chu by defining a single, uniform photon source of radius 25 microns and a single, 1 cm thick, scattering medium. For Test Case 1, the medium is defined to have no scattering or absorption. Figure 9 shows the simulation model.

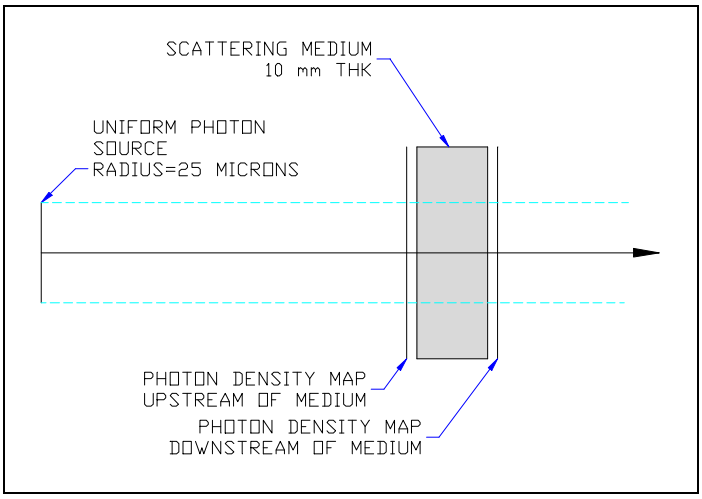


Figure 9 – Model Setup for Test Case 1

In Test Case 1, two photon density maps are defined to capture the *x* and *y* coordinates of the photons as they pass through, creating an image of the beam. One photon density map is located 1 micron upstream of the scattering medium, the other photon density map is located 1 micron downstream of the scattering medium.

Segments of the input file showing the definition of the scattering medium, photon source, and density maps are shown below.

```
Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //1000 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 1 //x, y, z coords of first point
  p1 1 -1 1 //x, y, z coords of second point
  p2 1 1 1 //x, y, z coords of third point
  p3 -1 1 1 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box
```

```
PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 100000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam upstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .999999 //x, y, z coords of first point
  p1 -1  1 .999999 //x, y, z coords of second point
  p2 -1 -1 .999999 //x, y, z coords of third point
  p3  1 -1 .999999 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam downstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 1.010001 //x, y, z coords of first point
  p1 -1  1 1.010001 //x, y, z coords of second point
  p2 -1 -1 1.010001 //x, y, z coords of third point
  p3  1 -1 1.010001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

The output file contains the density map "images" showing the photon density with columns showing the *x* coordinate and rows showing the *y* coordinate of the photon position as it passes through the density maps. Figures 10 and 11 show contour plots of the density map data (created by importing the density map into Microsoft Excel 2000 and graphing the data using the Surface Plot option with a contour interval of 500). It can be seen that the photon beam is indeed uniform and circular and that it is unaffected by the scattering medium.

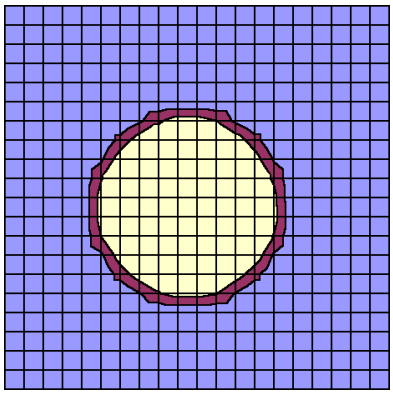


Figure 10 – Test Case 1: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Scattering Medium

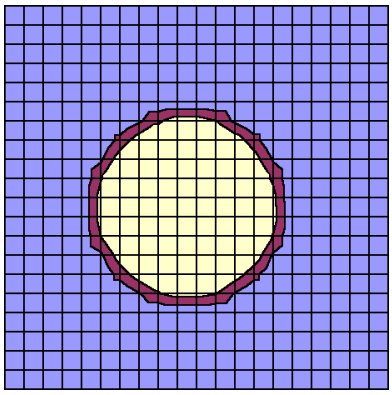


Figure 11 – Test Case 1: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Scattering Medium

Test Case 2 – A Single Medium with Scattering but without Absorption

To see the effect of scattering, the scattering medium of Test Case 1 is modified to have a scattering ratio of 1000 and a photon source of 1 million photons with all other model definitions being the same as Test Case 1.

Figures 12 and 13 show contour plots of the density map data upstream and downstream of the scattering medium (contour interval of 5000 for Figure 12 and contour interval of 10 for Figure 13). It can be seen

that the photon beam upstream of the medium is still uniform while the downstream image is distorted and is due mainly to the ballistic photons. Examination of the density map data shows that the intensity of the downstream image is approximately 1/1000th of the upstream image, as expected by the scatter ratio of 1000 used for the scattering medium.

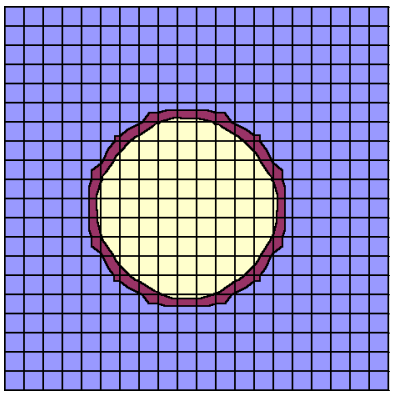


Figure 12 – Test Case 2: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Scattering Medium

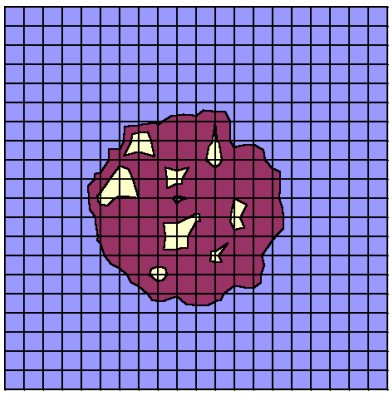


Figure 13 – Test Case 2: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Scattering Medium

Test Case 3 – A Single Medium with Scattering Using 50,000,000 Photons

Figures 12 and 13 do not show the expected scattering of the photons very clearly due to the low numbers of photons used (1 million). To increase the number of scattered photons per bin, Test Case 2 is modified to have a photon source with 50 million photons with all other model definitions being the same as Test Case 2.

Figures 14 and 15 show contour plots of the density map data upstream and downstream of the scattering medium with the maximum plotted value limited to 100 photons per bin in order to emphasis low order noise. It can be seen that the image of the photon beam upstream of the medium is blurred, due to backscattered photons. It should be noted that the average number of photons in each bin within the radius of the beam is 636,000 while the average number of backscattered photons captured in bins outside of the beam is approximately 70.

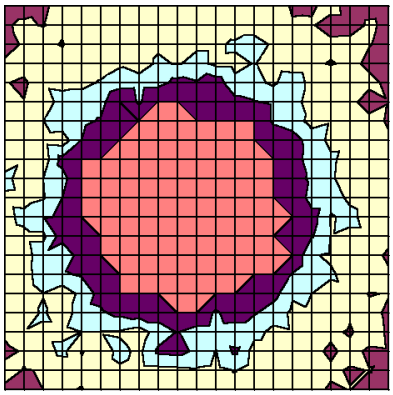


Figure 14 – Test Case 3: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Scattering Medium

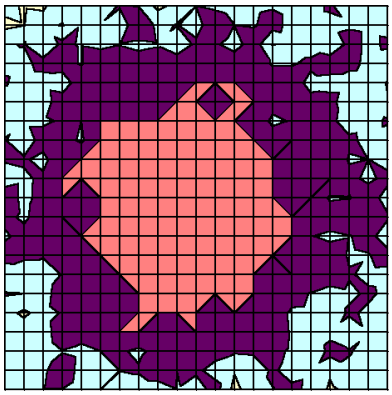


Figure 15 – Test Case 3: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Scattering Medium

The image downstream of the medium clearly shows signs of scattering. The circular beam is still visible, due primarily to ballistic photons, while the edges have been blurred. The average number of photons in each bin within the radius of the beam is approximately 800 while the average number of scattered photons captured in bins outside of the beam is approximately 80. This image shows the expected behaviour of becoming more uniform as the scattering level is increased. It would be expected that if the scattering level was increased further and the number of photons increased also (to maintain a reasonable number of photons per bin), then the beam would eventually become indistinguishable from the background noise of the scattered photons.

Test Case 4 – Comparison of Quasi-Ballistic to Ballistic Photons for a Single Scattering Medium with a Collimating Hole

In earlier work Chu and Pfeiffer compared the number of quasi-ballistic photons to ballistic photons for a range of scattering ratios and anisotropy factors using Monte Carlo simulation. A portion of those results are shown in Table 4.

Table 4 – Simulation Results for Uniform Source, 100,000,000 photons per run, no absorption, collimating array in place (50 micron diameter holes, 1 cm long, directly against sample)

Scattering Level	g	No. of Ballistic Photons	No. of Quasi-Ballistic Photons	No. of Scattered Photons
0.9	0.9	9950944	3525	38
0.99	0.9	1000727	718	17
0.999	0.9	100078	102	4
0.9999	0.9	9906	15	5
0.99999	0.9	966	3	0
0.999999	0.9	108	1	0

The base algorithms used by the PTS software are similar to those used by Chu and Pfeiffer and should yield similar results (although not exact as reflection, refraction and other differences do exist between the software). A single simulation model is constructed with the PTS software at a scattering ratio of 1000 (equivalent to a scattering level of 0.999) and a *g* factor of 0.9 using the simulation setup shown in Figure 16. It is expected that the numbers of ballistic, quasi-ballistic, and scattered photons will be similar to the values in the Table 4 for that scattering level and *g* factor.

This simulation model consists of a single, uniform photon source of radius 25 microns and a single, 1 cm thick, scattering medium with a scattering ratio of 1000. Downstream of the scattering medium is a 1 cm thick by 25 micron radius collimating hole constructed by embedding a cylinder of air in an absorbing cube. Multiple photon density maps downstream of the hole act as detectors.

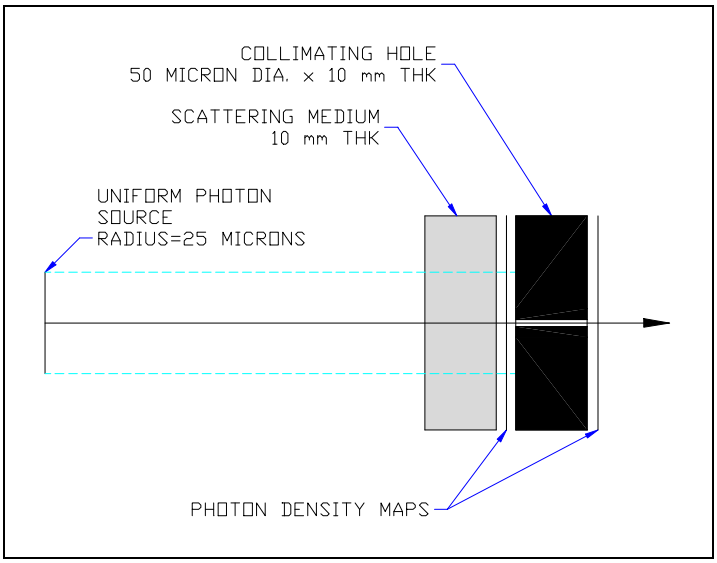


Figure 16 – Model Setup for Test Case 4

Figures 17 and 18 show the images from photon *x*-*y* density maps (50 photons per bin contour levels) located upstream and downstream of the collimating hole. It can be seen that the collimating hole assembly (comprised of a blocking medium and a cylinder of air) effectively blocks all photons that do not pass through the hole.

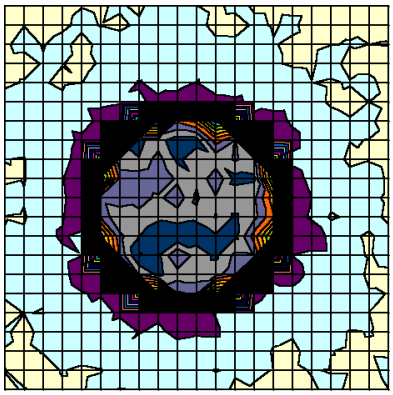


Figure 17 – Test Case 4: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Collimating Hole

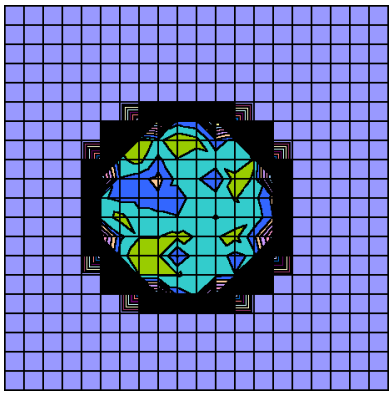


Figure 18 – Test Case 4: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Collimating Hole

In order to determine the number of ballistic, quasi-ballistic, and scattered photons passing through the collimating hole, additional density maps are defined.

```
Map //define a density map
  id "scattercount vs radial position wrt source downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRSOURCE 0 0.000050 0.000005 //hash lookup, radial pos wrt source
```

```
  idxrow "row index1" hash PHOTSCATTERCOUNT 0 50 1 //hash lookup, scattercount

Map //define a density map
  id "scattercount vs radial position wrt start pos downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRSTART 0 0.000050 0.000005 //hash lookup, radial pos wrt start
  idxrow "row index1" hash PHOTSCATTERCOUNT 0 50 1 //hash lookup, scattercount

Map //define a density map
  id "max radial deviation wrt source vs. max radial deviation wrt start pos downstream of
collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRMAXSOURCE 0 0.000050 0.000005 //hash, max radial pos wrt source
  idxrow "row index1" hash PHOTPOSRMAXSTART 0 0.000050 0.000005 //hash, max radial pos wrt start
```

The first two density maps related the number of times that a photon that passes through the collimating hole has been scattered to the radial position of the photon. Two different radial distance measures are used for comparison, the first uses the radial distance from the center of the photon source, the second uses the radial distance from the starting position of the photon. Tables 5 and 6 show portions of these density maps.

Table 5 – Test Case 4: Portion of Density Map Located Downstream of Collimating Hole Relating Radial Distance wrt Center of Photon Source to Number of Scattering Events

	Radial Distance wrt Center of Source (microns)					
No. of Scatter Events	**0**	**5**	**10**	**15**	**20**	**25**
0	4007	11867	19872	28263	35906	0
1	0	13	12	22	48	12
2	0	4	1	3	4	0
3	0	0	0	1	1	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	1	0

Table 6 – Test Case 4: Portion of Density Map Located Downstream of Collimating Hole Relating Radial Distance wrt Photon Starting Position to Number of Scattering Events

	Radial Distance wrt Center of Source (microns)										
No. of Scatter Events	0	5	10	15	20	25	30	35	40	45	50
0	99915	0	0	0	0	0	0	0	0	0	0
1	4	5	21	7	16	17	13	14	6	5	0
2	1	1	1	0	4	2	2	0	1	0	0
3	0	0	0	0	1	0	1	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	0	0	0	0	0	0

It can be seen that the number of ballistic photons is 99,915 in both tables (photons that underwent zero scattering events), although Table 5 shows these photons radially distributed (based upon the uniform source distribution) while Table 6 shows all of the ballistic photons binned into one cell.

It is not possible to determine the number of quasi-ballistic photons from Tables 5 or 6, although the total number of photons reaching the density maps can be determined to be 100,038 by summing all cells in either density map.

The determination of the quantity of quasi-ballistic photons depends upon the definition of what constitutes a quasi-ballistic photon. The results shown in Table 4 were calculated by considering a quasi-ballistic photon to be one that underwent at least one scattering event and did not "wander" to a position that was outside of a cylinder centered on the photon source with a radius of 30 microns. However, photons that are launched near the outer edge of the photon source (25 microns) do not have to wander very far in the radial direction before leaving the cylinder, but must wander up to 50 microns in the opposite direction (across the cylinder) to exit the cylinder. To avoid this asymmetry, a quasi-ballistic photon can be defined as a photon that does not wander outside of a cylinder centered on its starting position with an axis oriented along the initial photon trajectory. Table 7 shows the last density map that implement these two methods of determining quasi-ballistic photons.

Table 7 – Test Case 4: Density Map Located Downstream of Collimating Hole Relating Maximum Radial Distance wrt Photon Source to Maximum Radial Distance wrt Photon Starting Position

	Maximum Radial Distance wrt Center of Source (microns)										
Maximum Radial Distance wrt Photon Starting Position (microns)	0	5	10	15	20	25	30	35	40	45	50
0	4007	11868	19872	28264	35908	0	0	0	0	0	0
5	0	0	3	1	2	0	0	0	0	0	0
10	0	0	2	9	10	0	0	0	0	0	0
15	0	0	1	1	4	2	0	0	0	0	0
20	0	0	1	7	11	1	0	0	0	0	0
25	0	0	0	5	12	3	0	0	0	0	0
30	0	0	0	3	10	3	0	0	1	0	0
35	0	0	0	0	13	1	0	0	0	0	0
40	0	0	0	0	3	4	0	0	0	0	0
45	0	0	0	0	1	3	1	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0

From Table 7, the number of photons that did not leave the 30 micron radius cylinder centered on the photon source is determined by summing all of the table bins in the columns from 0 to 25 microns (less than 30 microns) and subtracting the number of ballistic photons. The number of scattered photons is the difference between the total number of photons passing through the collimating hole and the sum of the ballistic and quasi-ballistic photons. From Table 7, the number of photons that did not leave the 30 micron radius cylinder centered on the photon starting positions is determined by summing all of the table bins in the rows from 0 to 25 microns (less than 30 microns) and subtracting the number of ballistic photons. Table 8 shows a summary of these derived quantities.

Table 8 –Test Case 4: Summary Ballistic, Quasi-Ballistic, and Scattered Photon Quantities from Tables 4 and 7

	No. of Ballistic Photons	No. of Quasi-Ballistic	No. of Scattered Photons
Using a Maximum Radial Distance wrt Center of Source of 30 microns	99915	120	3
Using a Maximum Radial Distance wrt Center of Starting Position of 30 microns	99915	79	44
Earlier work by Chu/Pfeiffer Using a Maximum Radial Distance wrt Center of Source of 30 microns	100078	102	4

It can be seen that the numbers of ballistic, quasi-ballistic, and scattered photons calculated by the PTS software compares closely when the same criteria is used to select quasi-ballistic photons.

Test Case 5 – A Point Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

Many of the features of the PST software are shown in Test Case 5. Figure 19 shows the model setup which consists of two 45 degree reflecting mirrors, a 10 x Gaussian beam expander, a 0.2 mm x 20 mm slit, a scattering medium, an array of three collimating holes, and appropriate photon density maps. This model emulates the experimental setup in use in the Clean Room at SFU.

While not particularly practical as an model setup (a uniform photon source located upstream of the slit would provide a less computational intensive supply of photons), this test case does show how mirrors, lenses, slits, and arrays of collimating holes may be combined to create complex simulations.

The mirrors are defined as cylindrical mediums with high index of refraction and are oriented by specifying the surface normal vector. Note that a non-unit normal vector is permitted as the PTS software normalizes the vector prior to commencing the simulation run. The output file shows this normalized unit vector.

```
Medium //define a scattering and absorbing medium
  id "mirror 1" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.10 0 9.5 //x, y, z coords of first point
  p1 0.10 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector 1 0 1 //normal vector for extrude

Medium //define a scattering and absorbing medium
  id "mirror 2" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 9.5 //x, y, z coords of first point
  p1 0 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector -1 0 -1 //normal vector for extrude
```

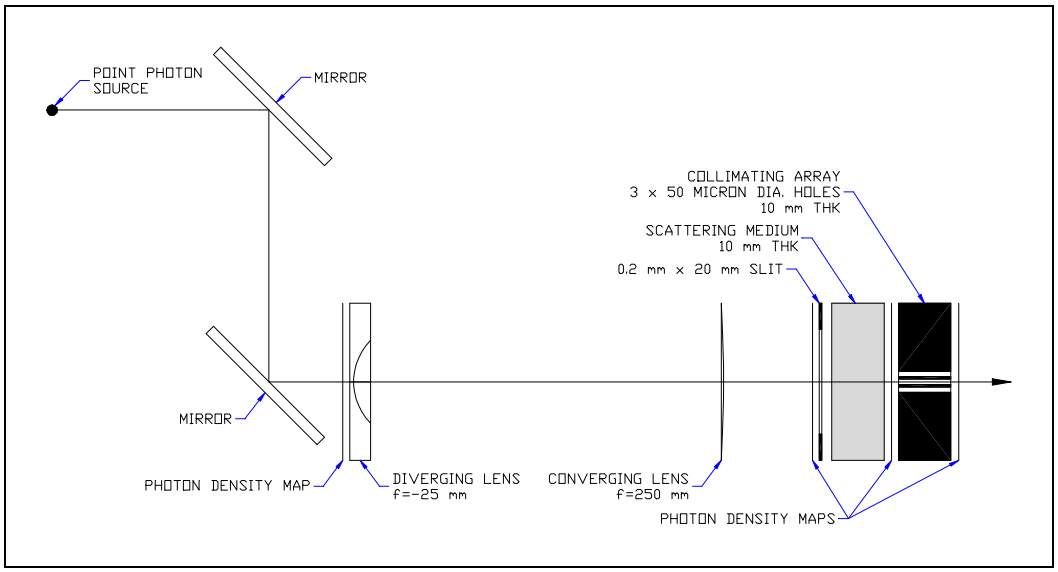


Figure 19 – Model Setup for Test Case 5

The diverging lens with a focal length of –25 mm is constructed by using two superimposed mediums. The first medium is a block of non-scattering, non-absorbing material with an index of refraction of 1.45. The second medium is a semi-sphere of non-scattering, non-absorbing material with an index of refraction of 1 (identical to the ambient medium).

```
Medium //define a scattering and absorbing medium
  id "diverging lens 1" //glass part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1.45 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10 //x, y, z coords of first point
  p1 0 0.015 10 //x, y, z coords of second point
  normalvector 0 0 1 //normal vector for extrude
  extrudelen  0.004 //extrusion length of cylinder

Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "diverging lens 2" //air part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 10.012 //x, y, z coords of first point
  p1 0 0.01125 10.012 //x, y, z coords of second point
  p3 0 0 10.004 //x, y, z coords of fourth point (cutting plane)
  normalvector 0 0 1 //normal vector of cut surface (plano side on right)
```

This combination forms a diverging lens with a plano side on the left in Figure 19 and the concave side on the right. The points p_0, p_1, and p_3 were selected to form a semi-sphere with a radius of 0.011250 m in accordance with the Lensmaker Formula (which applies to thin lenses operating in vacuum) below.

$$\frac{1}{f} = (n-1)\frac{1}{R}$$

where:

f = the focal distance (m)

n = the index of refraction of the lens medium

R = the radius of curvature of the lens (m)

At present, the PTS software does not support lens design explicitly, rather the user may specify geometry that can be used to model lenses.

A converging lens with a focal length of 250 mm forms the second optical element in the beam expander and its definition is shown below.

```
Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "converging lens"
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 2 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 9.9755 //x, y, z coords of first point
  p1 0 0.2485 9.9755 //x, y, z coords of second point
  p3 0 0 10.2235 //x, y, z coords of fourth point
  normalvector 0 0 -1 //normal vector of cut surface (plano side on left)
```

The Gaussian beam expander is formed when the focal points of the diverging and converging lenses are coincident. By placing the plano side of the converging lens approximately 225 mm from the plano side of the diverging lens (the actual distance used in the model is 223.5 mm), photons passing through the converging lens are refracted such that their trajectory is parallel to the z-axis. The magnification of this beam expander is the ratio of the focal lengths and is equal to 10. Test Case 6 will demonstrate the effect of the beam expander with a uniform photon source.

When using the silicon micromachined collimator array at SFU, it has proven useful to reduce the amount of light entering a scattering medium with a slit. Such an element is modeled in Test Case 5 by superimposing a cube of ambient medium on a cube of blocking medium. The following definitions show how a 0.2 mm x 20 mm slit is constructed.

```
Medium //define a scattering and absorbing medium
  id "slit blocking medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.25 //x, y, z coords of first point
  p1 1 -1 10.25 //x, y, z coords of second point
  p2 1 1 10.25 //x, y, z coords of third point
  p3 -1 1 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "slit opening medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -.01 -.0001 10.25 //x, y, z coords of first point
  p1 .01 -.0001 10.25 //x, y, z coords of second point
  p2 .01 .0001 10.25 //x, y, z coords of third point
  p3 -.01 .0001 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box
```

The array of three collimating holes is constructed by superimposing three cylinders of ambient material upon an absorbing cube. In order to eliminate internal reflection inside of the holes, the index of refraction of the blocking medium is set to 1, the same as the medium used for the holes. It is important to note that when photons are inside of multiple medium, the optical properties used are of the last medium defined. Hence, in the definition of the collimating array, the blocking medium is defined before the collimating holes.

```
Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.261 //x, y, z coords of first point
  p1 1 -1 10.261 //x, y, z coords of second point
  p2 1 1 10.261 //x, y, z coords of third point
```

```
  p3 -1 1 10.261 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator hole 1" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 -0.000100 0 10.261 //x, y, z coords of first point
  p1 -0.000100 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 2" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 3" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.000100 0 10.261 //x, y, z coords of first point
  p1 0.000100 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole
```

In order to verify the operation of the model, a single photon is launched from a point photon source. The photon is specified with a starting *x* coordinate of 0.10 m in order to align it with the center of the first mirror and a *y* coordinate of 2 microns to ensure that it will pass through the 25 micron radius center collimating hole (the *y* coordinate of the photon will become approximately 20 microns after passage through the 10 x beam expander).

```
PhotonSource //define a photon source
  id "point source 1"
  type POINT //point type of photon source
  p0 0.10 0 0  //x, y, z coords of center in cm
  p0 0.10 .000002 0  //x, y, z coords of center in cm
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1 //number of photons to launch from source
```

A photon density map, located after the collimating array, with the photon calculation type PHOTINFO is used to print a summary of the photon, including a list of its recorded positions, to the output file.

```
Map //define a density map
  id "photon info downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.271001 //x, y, z coords of first point
  p1 -1  1 10.271001 //x, y, z coords of second point
  p2 -1 -1 10.271001 //x, y, z coords of third point
  p3  1 -1 10.271001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTINFO 0 20 1 //hash lookup, movecount
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

The summary for the photon as it passes through that density map is shown below.

```
PhotonInfo //photon information
  posstart 0.1000000 0.0000020 0.0000000  //starting position
  trajstart 0.0000000 0.0000000 1.0000000  //starting trajectory
  poscurrent -0.0000000 0.0000198 10.2710010  //current position
  trajcurrent -0.0000000 0.0000002 1.0000000  //current trajectory
  medium ambient //current medium in which photon resides
  wavelength 514.000000 //wavelength of photon (nm)
  movecount 12 //number of moves made by photon
```

```
  scattercount 0 //number of scatter events
  reflectcount 2 //number of reflect events
  refractcount 10 //number of refract events
  pathlength 10.371001 //total pathlength (m)
  life 0.000000034610 //lifetime of photon (secs)
  desireddist 100000000000000000000.000000 //current desired distance
  photposrsource 0.100000 //radial component of current position (reference to the photon source
normal)
  photposrstart 0.100000 //radial component of current position (reference to the photon start
trajectory and pos)
  phottrajdotsource 1.000000 //dot product of current trajectory and photon source (cosine of forward
scattering angle
    for photons with starting trajectory equal to source normal)
  phottrajdotstart 1.000000 //dot product of current trajectory and photon starting trajectory
(cosine of forward scattering
    angle)
  photposrmaxsource 0.100000 //maximum radial component of any recorded position (reference to the
photon source
    normal)
  photposrmaxstart 0.100000 //maximum radial component of any recorded position (reference to the
photon start
    trajectory and pos)
  poslist 0.1000000 0.0000020 0.0000000  //starting position
  \       0.1000000 0.0000020 9.5000000
  \       -0.0000000 0.0000020 9.5000000
  \       -0.0000000 0.0000020 10.0000000
  \       -0.0000000 0.0000020 10.0007500
  \       -0.0000000 0.0000023 10.0040000
  \       -0.0000000 0.0000198 10.2235000
  \       -0.0000000 0.0000198 10.2240000
  \       -0.0000000 0.0000198 10.2500000
  \       -0.0000000 0.0000198 10.2505000
  \       -0.0000000 0.0000198 10.2510000
  \       -0.0000000 0.0000198 10.2610000
  \       -0.0000000 0.0000198 10.2710000  //last recorded position
```

It can be seen from the list of recorded positions that photon was reflected by the two 45 degree mirrors and through the beam expander. The *y* coordinate of the photon exiting the beam expander was approximately 10 times that of the *y* coordinate of the photon entering the beam expander (19.8 vs 2 microns). The photon passed through the collimator hole with a trajectory almost parallel to the z-axis (*dx*=0.0000000, *dy*= 0.0000002, *dz*=1.0000000) with the small errors due to alignment of the optics and the small circle of confusion of spherical lenses.

Test Case 6 – A Uniform Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

While Test Case 5 demonstrated the definition of a complex model, only a point photon source with a single photon was used. Test Case 6 uses the definition of Test Case 5, but substitutes a uniform photon source of 1.25 mm beam radius (2.5 mm diameter) in place of the point source.

```
PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0.10 0 0 //x, y, z coords of center in cm
  p1 0.10 0.00125 0 //x, y, z coords of point on circumference in cm
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1000000 //number of photons to launch from source
```

The effect of the beam expander can be seen in Figures 20 and 21. These figures, plotted as surface contour plots on a square photon *x*-*y* density map of width 25 mm, clearly show how the beam size is increased by the Gaussian beam expander. The intensity variations in the expanded beam are due to the low numbers of photons used (too few photons per density map bin).

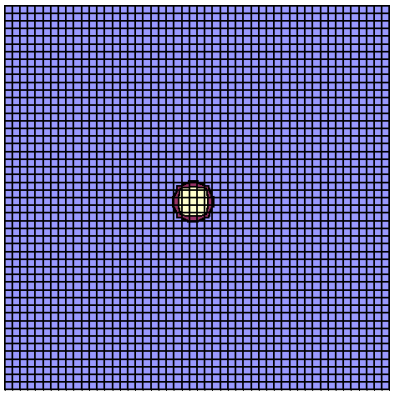


Figure 20 – Test Case 6: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Beam Expander

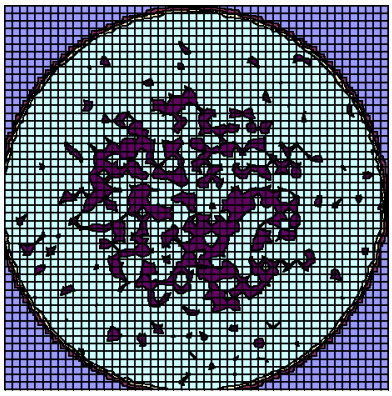


Figure 21 – Test Case 6: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Beam Expander

The slit acts to restrict the amount of light entering the scattering medium. The 0.2 mm high by 20 mm wide slit upstream of the scattering medium allows ballistic photons through to the linear collimator array, but blocks light that would otherwise contribute only to the scattered noise. Figures 22 and 23 show the images collected by *x*-*y* photon density maps located upstream and downstream of the collimating array. It should be noted that this simulation is conducted with a non-scattering medium so there is no scattering of the light from the slit to the first density map.

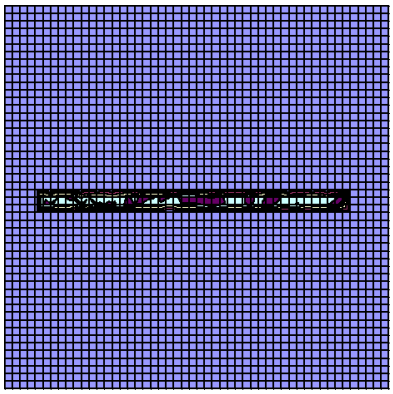


Figure 22 – Test Case 6: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Upstream of Beam Expander

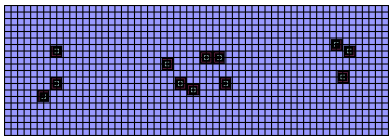


Figure 23 – Test Case 6: Plot of Photon Density as a Function of *x* Coordinate and *y* Coordinate Downstream of Beam Expander

Figure 22 shows a surface contour plot of a square photon *x*-*y* density map of width and height of 25 mm. Figure 23 shows a surface contour plot of a photon *x*-*y* density map of height 100 microns and width 300 microns centered on the middle collimator hole. The low resolution (groupings of single photons) of the post-collimator hole image is due to the combination of small bin size (5 microns x 5 microns) and low numbers of photons used (of the 1 million photons launched, only 6119 passed through the slit at an average intensity of 0.0015 photons per square micron). Using a photon source with a larger number of photons will more clearly define the three collimators holes shown in Figure 23.

Program Theory and Structure

Limitations in existing Monte Carlo simulation software for photon transport prompted the development of a completely new software tool, the *Photon Transport Simulator* by the author. This tool was designed to perform the same Monte Carlo simulations as existing software by Jacques and extended by Chu and Pfeiffer, but with multiple mediums, photon sources, and more flexible methods of capturing photon information and reporting results. In addition, the optical characteristics of reflection and refraction at object surfaces are fully supported.

The program can be thought of as a form of ray tracing, with individual photons forming the rays and user-defined image planes capturing the results. In the PTS software, photons are assumed to be discrete particles and only ballistic behaviour is modeled.

A full description of the software and its underlying modules is beyond the scope of this User Manual. The reader is referred to *Development of Software Tools for Simulation of Photon Transport in Scattering and Absorbing Media: the Photon Transport Simulator* for information on the overall program and to *Development of NURB Surface and Visualization Extensions to the Photon Transport Simulator* for information on the NURB surface and Scheme/ACIS extensions.

Hints and Tricks

Use a standard setup file (such as stdsetup.mci) to configure all models in a consistent manner. Include this setup file into the actual model input file using the #include statement. Copy this setup file into the same directory as the other .mci input files.

Set the PATH command to the directory containing the m1main12.exe file and then set the current directory to be the directory in which the .mci input files are located. This will shorten the command line. Output files (.mco and .scm) will be in the current directory unless output file names (including path) are specified.

The Scheme output file contains all of the medium objects, including the bounding box and the ambient media. Edit the .scm text file to delete the definitions for these objects before loading the Scheme file into ACIS. These two objects are larger than all other objects and will obscure the view of everything else.

Photon trajectories are represented in ACIS as wire bodies. In order to view the photon trajectory (and point photon sources) the OpenGL viewport must be configured to display edges and vertices.

Appendix A – Standard Setup Input File for all Test Cases

Input File stdsetup.mci

```
//standard setup file for Test Cases
//written by Nick Pfeiffer, Dec 27/02

RandomNumberGenerator //define the random number generator used for the simulation
  type MC //type of random number generator
  seed 0 //initial seed

Medium //define a scattering and absorbing medium
  id "bounding box"
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 100000000.0 //coefficient of absorption
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1001 -1001 -1001 //x, y, z coords of first point
  p1 1001 -1001 -1001 //x, y, z coords of second point
  p2 1001 1001 -1001 //x, y, z coords of third point
  p3 -1001 1001 -1001 //x, y, z coords of fourth point
  extrudelen 2002 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "ambient"
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1000 -1000 -1000 //x, y, z coords of first point
  p1 1000 -1000 -1000 //x, y, z coords of second point
  p2 1000 1000 -1000 //x, y, z coords of third point
  p3 -1000 1000 -1000 //x, y, z coords of fourth point
  extrudelen 2000 //extrusion length of box
```

Appendix B – Test Case 1 Input File

A Single Medium with No Scattering or Absorption

Input File testcase1.mci

```
RunInfo
  comment "Test Case 1"
  \       "A Single Medium with No Scattering or Absorption"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 1 //x, y, z coords of first point
  p1 1 -1 1 //x, y, z coords of second point
  p2 1 1 1 //x, y, z coords of third point
  p3 -1 1 1 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 100000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam upstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .999999 //x, y, z coords of first point
  p1 -1  1 .999999 //x, y, z coords of second point
  p2 -1 -1 .999999 //x, y, z coords of third point
  p3  1 -1 .999999 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam downstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 1.010001 //x, y, z coords of first point
  p1 -1  1 1.010001 //x, y, z coords of second point
  p2 -1 -1 1.010001 //x, y, z coords of third point
  p3  1 -1 1.010001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

Appendix C – Test Case 1 Output File

A Single Medium with No Scattering or Absorption

Output File testcase1.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 1"
  comment1 "A Single Medium with No Scattering or Absorption"
  comment2 ""
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase1.mci" //name of input file for this run
  outputfile "testcase1.mco" //name of output file for this run
  photonqty 100000 //total number of photons in all sources
  runstart Fri Dec 27 17:06:28 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.0000000 -1001.0000000 -1001.0000000  //point 0 (center for circle)
  p1 1001.0000000 -1001.0000000 -1001.0000000  //point 1
  p2 1001.0000000 1001.0000000 -1001.0000000  //point 2
  p3 -1001.0000000 1001.0000000 -1001.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "ambient" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.0000000 -1000.0000000 -1000.0000000  //point 0 (center for circle)
  p1 1000.0000000 -1000.0000000 -1000.0000000  //point 1
  p2 1000.0000000 1000.0000000 -1000.0000000  //point 2
  p3 -1000.0000000 1000.0000000 -1000.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 1.0000000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 1.0000000  //point 1
  p2 1.0000000 1.0000000 1.0000000  //point 2
  p3 -1.0000000 1.0000000 1.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 100000 //initial number of photons in source to launch
  //qtyleft 100000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
```

```
  p0 0.0000000 0.0000000 0.0000000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 0.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

RunInfo
  runend Fri Dec 27 17:06:40 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam upstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 0.9999990  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 0.9999990  //point 1
  p2 -1.0000000 -1.0000000 0.9999990  //point 2
  p3 1.0000000 -1.0000000 0.9999990  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000050
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000030
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00          443.00          963.00         1206.00         1216.00         1034.00          450.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
691.00         1271.00         1225.00         1273.00         1247.00         1251.00         1264.00
690.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000020
  \               0.00            0.00            0.00            0.00            0.00          384.00
1260.00         1232.00         1297.00         1295.00         1233.00         1267.00
1223.00         1352.00          432.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.000015
  \               0.00            0.00            0.00            0.00            0.00         1004.00
1317.00         1230.00         1269.00         1282.00         1333.00         1282.00
1262.00         1290.00          974.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.000010
  \               0.00            0.00            0.00            0.00            0.00         1225.00
1283.00         1246.00         1263.00         1304.00         1257.00         1234.00
1334.00         1264.00         1196.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.000005
  \               0.00            0.00            0.00            0.00            0.00         1220.00
1238.00         1302.00         1241.00         1259.00         1187.00         1256.00
1270.00         1236.00         1129.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.000000
  \               0.00            0.00            0.00            0.00            0.00          961.00
1333.00         1263.00         1228.00         1284.00         1279.00         1327.00
1286.00         1285.00          944.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.000005
  \               0.00            0.00            0.00            0.00            0.00          404.00
1291.00         1277.00         1290.00         1294.00         1230.00         1259.00
1299.00         1248.00          442.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.000010
  \               0.00            0.00            0.00            0.00            0.00            0.00
686.00         1290.00         1296.00         1281.00         1273.00         1306.00         1316.00
710.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000015
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00          407.00          931.00         1246.00         1242.00         1007.00          399.00
```

```
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000020
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000025
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000030
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000035
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000040
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000045
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000050

Map //define a photon density map
  id "x-y pos of beam downstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 1.0100010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 1.0100010  //point 1
  p2 -1.0000000 -1.0000000 1.0100010  //point 2
  p3 1.0000000 -1.0000000 1.0100010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000050
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000045
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000040
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000035
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000030
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00          443.00          963.00         1206.00         1216.00         1034.00          450.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000025
  \               0.00           0.00           0.00           0.00           0.00           0.00
691.00         1271.00         1225.00         1273.00         1247.00         1251.00         1264.00
690.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000020
  \               0.00           0.00           0.00           0.00           0.00          384.00
1260.00         1232.00         1297.00         1295.00         1233.00         1267.00
1223.00         1352.00          432.00            0.00            0.00            0.00
0.00            0.00           0.00 //-0.000015
  \               0.00           0.00           0.00           0.00           0.00         1004.00
1317.00         1230.00         1269.00         1282.00         1333.00         1282.00
1262.00         1290.00          974.00            0.00            0.00            0.00
0.00            0.00           0.00 //-0.000010
  \               0.00           0.00           0.00           0.00           0.00         1225.00
1283.00         1246.00         1263.00         1304.00         1257.00         1234.00
1334.00         1264.00         1196.00            0.00            0.00            0.00
0.00            0.00           0.00 //-0.000005
  \               0.00           0.00           0.00           0.00           0.00         1220.00
1238.00         1302.00         1241.00         1259.00         1187.00         1256.00
1270.00         1236.00         1129.00            0.00            0.00            0.00
0.00            0.00           0.00 //0.000000
```

```
  \               0.00            0.00            0.00            0.00            0.00          961.00
1333.00         1263.00         1228.00         1284.00         1279.00         1327.00
1286.00         1285.00          944.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.000005
  \               0.00            0.00            0.00            0.00            0.00          404.00
1291.00         1277.00         1290.00         1294.00         1230.00         1259.00
1299.00         1248.00          442.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.000010
  \               0.00            0.00            0.00            0.00            0.00            0.00
686.00         1290.00         1296.00         1281.00         1273.00         1306.00         1316.00
710.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000015
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00           407.00          931.00         1246.00         1242.00         1007.00          399.00
0.00              0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000020
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000030
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000050
```

Appendix D – Test Case 2 Input File

A Single Medium with Scattering but without Absorption

Input File testcase2.mci

```
RunInfo
  comment "Test Case 2"
  \       "A Single Medium with Scattering but without Absorption"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 1000 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 1 //x, y, z coords of first point
  p1 1 -1 1 //x, y, z coords of second point
  p2 1 1 1 //x, y, z coords of third point
  p3 -1 1 1 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1000000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam upstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .999999 //x, y, z coords of first point
  p1 -1  1 .999999 //x, y, z coords of second point
  p2 -1 -1 .999999 //x, y, z coords of third point
  p3  1 -1 .999999 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam downstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 1.010001 //x, y, z coords of first point
  p1 -1  1 1.010001 //x, y, z coords of second point
  p2 -1 -1 1.010001 //x, y, z coords of third point
  p3  1 -1 1.010001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

Appendix E – Test Case 2 Output File

A Single Medium with Scattering but without Absorption

Output File testcase2.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 2"
  comment1 "A Single Medium with Scattering but without Absorption"
  comment2 ""
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase2.mci" //name of input file for this run
  outputfile "testcase2.mco" //name of output file for this run
  photonqty 1000000 //total number of photons in all sources
  runstart Fri Dec 27 20:07:42 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.0000000 -1001.0000000 -1001.0000000  //point 0 (center for circle)
  p1 1001.0000000 -1001.0000000 -1001.0000000  //point 1
  p2 1001.0000000 1001.0000000 -1001.0000000  //point 2
  p3 -1001.0000000 1001.0000000 -1001.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "ambient" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.0000000 -1000.0000000 -1000.0000000  //point 0 (center for circle)
  p1 1000.0000000 -1000.0000000 -1000.0000000  //point 1
  p2 1000.0000000 1000.0000000 -1000.0000000  //point 2
  p3 -1000.0000000 1000.0000000 -1000.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 690.875478 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 1000.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 690.875478 //extinction coefficient (m^-1)
  //albedo 1.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 1.0000000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 1.0000000  //point 1
  p2 1.0000000 1.0000000 1.0000000  //point 2
  p3 -1.0000000 1.0000000 1.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 1000000 //initial number of photons in source to launch
  //qtyleft 1000000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
```

```
  p0 0.0000000 0.0000000 0.0000000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 0.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

RunInfo
  runend Fri Dec 27 20:15:37 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam upstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 0.9999990  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 0.9999990  //point 1
  p2 -1.0000000 -1.0000000 0.9999990  //point 2
  p3 1.0000000 -1.0000000 0.9999990  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data            0.00            1.00            0.00            2.00            0.00            0.00
0.00            1.00            1.00            3.00            1.00            1.00            2.00
1.00            0.00            1.00            0.00            0.00            4.00            0.00
1.00 //-0.000050
  \               3.00            0.00            2.00            2.00            0.00            0.00
1.00            3.00            2.00            3.00            0.00            1.00            0.00
2.00            0.00            3.00            0.00            1.00            0.00            3.00
1.00 //-0.000045
  \               0.00            1.00            1.00            0.00            1.00            1.00
2.00            0.00            0.00            0.00            4.00            1.00            1.00
2.00            0.00            1.00            2.00            0.00            0.00            0.00
0.00 //-0.000040
  \               0.00            2.00            1.00            0.00            0.00            1.00
2.00            1.00            1.00            0.00            2.00            2.00            2.00
4.00            1.00            1.00            1.00            1.00            1.00            2.00
0.00 //-0.000035
  \               2.00            1.00            1.00            0.00            2.00            4.00
1.00            2.00            2.00            1.00            4.00            1.00            0.00
2.00            1.00            1.00            3.00            2.00            1.00            2.00
1.00 //-0.000030
  \               1.00            1.00            0.00            1.00            3.00            1.00
3.00         3986.00         9506.00        12417.00        12324.00         9648.00         4139.00
3.00            2.00            1.00            0.00            0.00            5.00            0.00
1.00 //-0.000025
  \               0.00            0.00            2.00            3.00            1.00            2.00
6949.00        12537.00        12854.00        12947.00        12831.00        12878.00
12654.00         6918.00            4.00            2.00            1.00            3.00
1.00            2.00            1.00 //-0.000020
  \               2.00            0.00            1.00            1.00            1.00         4078.00
12613.00        12633.00        13037.00        12680.00        12647.00        12846.00
12617.00        12724.00         3880.00            6.00            1.00            1.00
0.00            2.00            1.00 //-0.000015
  \               1.00            1.00            2.00            1.00            2.00         9689.00
12909.00        12547.00        12816.00        12837.00        12550.00        12760.00
12756.00        12880.00         9630.00            2.00            2.00            1.00
0.00            1.00            2.00 //-0.000010
  \               0.00            4.00            2.00            0.00            1.00        12168.00
12928.00        12861.00        12577.00        12503.00        12704.00        12552.00
12923.00        12760.00        12220.00            2.00            2.00            2.00
3.00            3.00            1.00 //-0.000005
  \               2.00            1.00            1.00            0.00            3.00        12340.00
12758.00        12680.00        12786.00        12730.00        12863.00        12736.00
12595.00        12793.00        12492.00            1.00            1.00            0.00
1.00            2.00            2.00 //0.000000
  \               1.00            4.00            1.00            4.00            3.00         9681.00
12762.00        12820.00        12703.00        12689.00        12648.00        12852.00
12969.00        12755.00         9718.00            2.00            2.00            4.00
1.00            1.00            0.00 //0.000005
  \               0.00            1.00            0.00            3.00            1.00         3914.00
12508.00        12835.00        12547.00        12688.00        12725.00        12719.00
12820.00        12709.00         4143.00            0.00            1.00            0.00
0.00            1.00            2.00 //0.000010
  \               1.00            0.00            0.00            0.00            0.00            3.00
6830.00        12652.00        13004.00        12532.00        12531.00        12718.00
12916.00         6958.00            1.00            2.00            0.00            1.00
2.00            1.00            2.00 //0.000015
  \               0.00            1.00            2.00            0.00            2.00            0.00
5.00         4060.00         9715.00        12452.00        12239.00         9609.00         4139.00
```

```
1.00            2.00            1.00            1.00            2.00            1.00            2.00
3.00 //0.000020
  \               2.00            0.00            2.00            1.00            1.00            0.00
2.00            5.00            2.00            1.00            4.00            2.00            2.00
1.00            1.00            1.00            0.00            1.00            0.00            1.00
0.00 //0.000025
  \               1.00            1.00            3.00            2.00            2.00            2.00
0.00            1.00            1.00            1.00            2.00            1.00            1.00
3.00            1.00            0.00            1.00            0.00            1.00            2.00
1.00 //0.000030
  \               0.00            0.00            0.00            1.00            2.00            1.00
1.00            5.00            2.00            0.00            0.00            4.00            0.00
1.00            1.00            1.00            0.00            1.00            0.00            1.00
0.00 //0.000035
  \               2.00            2.00            1.00            0.00            2.00            1.00
1.00            0.00            2.00            0.00            2.00            0.00            1.00
2.00            0.00            2.00            0.00            1.00            4.00            0.00
1.00 //0.000040
  \               0.00            1.00            0.00            0.00            0.00            0.00
1.00            0.00            0.00            2.00            1.00            1.00            1.00
0.00            2.00            1.00            2.00            0.00            1.00            1.00
1.00 //0.000045
  \               1.00            0.00            1.00            1.00            0.00            2.00
1.00            0.00            2.00            1.00            1.00            0.00            2.00
1.00            0.00            0.00            1.00            1.00            1.00            1.00
0.00 //0.000050

Map //define a photon density map
  id "x-y pos of beam downstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 1.0100010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 1.0100010  //point 1
  p2 -1.0000000 -1.0000000 1.0100010  //point 2
  p3 1.0000000 -1.0000000 1.0100010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data            1.00            0.00            1.00            1.00            6.00            2.00
4.00            1.00            0.00            1.00            2.00            3.00            0.00
2.00            1.00            0.00            0.00            0.00            0.00            1.00
1.00 //-0.000050
  \               0.00            2.00            3.00            5.00            1.00            2.00
0.00            4.00            7.00            0.00            2.00            2.00            2.00
0.00            1.00            2.00            1.00            0.00            0.00            0.00
2.00 //-0.000045
  \               3.00            3.00            1.00            0.00            2.00            1.00
1.00            0.00            0.00            0.00            1.00            0.00            1.00
2.00            2.00            1.00            1.00            1.00            4.00            2.00
0.00 //-0.000040
  \               1.00            1.00            2.00            2.00            1.00            2.00
3.00            2.00            2.00            1.00            4.00            3.00            2.00
0.00            0.00            1.00            0.00            1.00            0.00            0.00
3.00 //-0.000035
  \               5.00            4.00            1.00            1.00            2.00            2.00
1.00            0.00            3.00            2.00            4.00            4.00            1.00
3.00            2.00            1.00            1.00            2.00            1.00            3.00
0.00 //-0.000030
  \               1.00            1.00            1.00            1.00            1.00            1.00
0.00            6.00           14.00           11.00           19.00           14.00            5.00
7.00            1.00            1.00            0.00            0.00            1.00            3.00
3.00 //-0.000025
  \               2.00            4.00            0.00            1.00            2.00            1.00
6.00           16.00           23.00           17.00           14.00           16.00           16.00
16.00           0.00            1.00            3.00            2.00            3.00            1.00
0.00 //-0.000020
  \               1.00            2.00            4.00            3.00            5.00            8.00
17.00           14.00           16.00           15.00           13.00           22.00           11.00
14.00            5.00            0.00            2.00            2.00            1.00            1.00
0.00 //-0.000015
  \               0.00            0.00            3.00            1.00            1.00           11.00
12.00           15.00           14.00           29.00           13.00           13.00           19.00
18.00           11.00            3.00            1.00            0.00            1.00            2.00
4.00 //-0.000010
  \               3.00            3.00            2.00            1.00            0.00           13.00
15.00           10.00           16.00           16.00           22.00           11.00           22.00
15.00           19.00            3.00            6.00            2.00            1.00            2.00
2.00 //-0.000005
  \               2.00            1.00            0.00            1.00            1.00           23.00
19.00           20.00           17.00            8.00           12.00           11.00           20.00
19.00           15.00            1.00            3.00            3.00            1.00            3.00
3.00 //0.000000
```

```
  \              2.00          2.00          0.00          4.00          3.00          13.00
27.00          17.00         17.00         23.00         12.00         17.00         13.00
15.00          16.00          0.00          1.00          1.00          6.00          3.00
2.00 //0.000005
  \              2.00          2.00          1.00          1.00          2.00          4.00
17.00          13.00         18.00         16.00         18.00         22.00         16.00
18.00           5.00          1.00          0.00          1.00          1.00          2.00
1.00 //0.000010
  \              1.00          2.00          0.00          1.00          1.00          4.00
4.00           30.00         15.00         18.00         12.00         21.00         7.00
8.00            2.00          4.00          1.00          0.00          3.00          0.00
0.00 //0.000015
  \              3.00          1.00          4.00          2.00          1.00          2.00
2.00           6.00          9.00         14.00         13.00         20.00         7.00
3.00           1.00          2.00          0.00          2.00          3.00          3.00
1.00 //0.000020
  \              1.00          2.00          0.00          5.00          3.00          1.00
1.00           2.00          1.00          2.00          3.00          1.00          1.00
2.00           1.00          2.00          1.00          2.00          0.00          1.00
3.00 //0.000025
  \              2.00          1.00          2.00          1.00          5.00          0.00
4.00           0.00          0.00          3.00          0.00          1.00          3.00
1.00           3.00          3.00          0.00          0.00          2.00          0.00
0.00 //0.000030
  \              0.00          2.00          1.00          2.00          0.00          1.00
1.00           4.00          1.00          4.00          2.00          1.00          1.00
4.00           2.00          1.00          2.00          2.00          1.00          3.00
1.00 //0.000035
  \              2.00          1.00          0.00          1.00          2.00          3.00
1.00           2.00          2.00          3.00          1.00          0.00          4.00
3.00           1.00          1.00          2.00          2.00          2.00          2.00
3.00 //0.000040
  \              2.00          0.00          1.00          1.00          0.00          1.00
1.00           3.00          2.00          0.00          0.00          2.00          2.00
4.00           1.00          1.00          3.00          3.00          1.00          3.00
1.00 //0.000045
  \              0.00          1.00          0.00          2.00          2.00          1.00
1.00           1.00          3.00          0.00          1.00          2.00          2.00
3.00           2.00          3.00          3.00          1.00          1.00          0.00
2.00 //0.000050
```

Appendix F – Test Case 3 Input File

A Single Medium with Scattering Using 50,000,000 Photons

Input File testcase3.mci

```
RunInfo
  comment "Test Case 3"
  \       "A Single Medium with Scattering but without Absorption"
  \       "Photon Source with 50 million photons"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 1000 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 1 //x, y, z coords of first point
  p1 1 -1 1 //x, y, z coords of second point
  p2 1 1 1 //x, y, z coords of third point
  p3 -1 1 1 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 50000000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam upstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .999999 //x, y, z coords of first point
  p1 -1  1 .999999 //x, y, z coords of second point
  p2 -1 -1 .999999 //x, y, z coords of third point
  p3  1 -1 .999999 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam downstream of scattering medium"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 1.010001 //x, y, z coords of first point
  p1 -1  1 1.010001 //x, y, z coords of second point
  p2 -1 -1 1.010001 //x, y, z coords of third point
  p3  1 -1 1.010001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

Appendix G – Test Case 3 Output File

A Single Medium with Scattering Using 50,000,000 Photons

Output File testcase3.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 3"
  comment1 "A Single Medium with Scattering but without Absorption"
  comment2 "Photon Source with 50 million photons"
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase3.mci" //name of input file for this run
  outputfile "testcase3.mco" //name of output file for this run
  photonqty 50000000 //total number of photons in all sources
  runstart Fri Dec 27 22:27:15 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.0000000 -1001.0000000 -1001.0000000  //point 0 (center for circle)
  p1 1001.0000000 -1001.0000000 -1001.0000000  //point 1
  p2 1001.0000000 1001.0000000 -1001.0000000  //point 2
  p3 -1001.0000000 1001.0000000 -1001.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "ambient" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.0000000 -1000.0000000 -1000.0000000  //point 0 (center for circle)
  p1 1000.0000000 -1000.0000000 -1000.0000000  //point 1
  p2 1000.0000000 1000.0000000 -1000.0000000  //point 2
  p3 -1000.0000000 1000.0000000 -1000.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 690.875478 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 1000.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 690.875478 //extinction coefficient (m^-1)
  //albedo 1.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 1.0000000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 1.0000000  //point 1
  p2 1.0000000 1.0000000 1.0000000  //point 2
  p3 -1.0000000 1.0000000 1.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 50000000 //initial number of photons in source to launch
  //qtyleft 50000000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
```

```
  p0 0.0000000 0.0000000 0.0000000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 0.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

RunInfo
  runend Sat Dec 28 03:51:35 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam upstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 0.9999990  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 0.9999990  //point 1
  p2 -1.0000000 -1.0000000 0.9999990  //point 2
  p3 1.0000000 -1.0000000 0.9999990  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data           35.00           25.00           40.00           43.00           39.00           48.00
49.00           57.00           52.00           45.00           44.00           50.00           40.00
43.00           51.00           45.00           49.00           36.00           41.00           19.00
31.00 //-0.000050
  \             49.00           39.00           41.00           40.00           44.00           48.00
56.00           51.00           53.00           54.00           57.00           54.00           61.00
49.00           50.00           58.00           49.00           45.00           37.00           41.00
24.00 //-0.000045
  \             33.00           43.00           48.00           66.00           39.00           46.00
67.00           55.00           84.00           86.00           76.00           59.00           84.00
51.00           49.00           46.00           47.00           35.00           50.00           34.00
37.00 //-0.000040
  \             45.00           59.00           54.00           55.00           60.00           59.00
57.00           48.00           70.00           81.00           70.00           70.00           64.00
67.00           54.00           58.00           53.00           45.00           37.00           57.00
35.00 //-0.000035
  \             44.00           42.00           64.00           44.00           73.00           77.00
85.00           91.00           89.00          117.00          105.00           76.00           93.00
82.00           70.00           56.00           59.00           55.00           43.00           51.00
33.00 //-0.000030
  \             53.00           47.00           59.00           46.00           66.00           87.00
100.00       201550.00       483492.00       615161.00       614296.00       484038.00       201615.00
96.00           87.00           62.00           60.00           50.00           55.00           38.00
42.00 //-0.000025
  \             52.00           48.00           74.00           77.00           82.00           82.00
346731.00       636874.00       636816.00       639634.00       638384.00       638662.00
637897.00       348044.00          106.00           78.00           60.00           63.00
50.00           57.00           44.00 //-0.000020
  \             57.00           47.00           76.00           60.00           92.00       202228.00
636799.00       637399.00       639659.00       636614.00       636713.00       636691.00
637967.00       638248.00       202007.00          100.00           62.00           57.00
46.00           48.00           36.00 //-0.000015
  \             49.00           53.00           55.00           91.00           90.00       483931.00
637973.00       637682.00       636662.00       637267.00       637064.00       637554.00
636346.00       637343.00       483471.00           85.00           82.00           59.00
54.00           55.00           47.00 //-0.000010
  \             51.00           67.00           79.00           81.00          103.00       614743.00
637274.00       637319.00       636240.00       635696.00       635237.00       636699.00
636935.00       638934.00       615785.00          112.00           89.00           58.00
66.00           50.00           49.00 //-0.000005
  \             54.00           51.00           58.00           80.00          104.00       614386.00
636640.00       635403.00       636816.00       636046.00       635580.00       636913.00
638575.00       637263.00       617142.00           99.00           71.00           68.00
56.00           50.00           44.00 //0.000000
  \             71.00           43.00           60.00           73.00          102.00       483541.00
637380.00       637674.00       635273.00       635342.00       635978.00       636835.00
637036.00       637487.00       484250.00           88.00           76.00           62.00
51.00           60.00           44.00 //0.000005
  \             40.00           55.00           48.00           87.00          103.00       200802.00
634739.00       636584.00       634642.00       637046.00       636808.00       637370.00
637301.00       636635.00       202864.00           91.00           69.00           63.00
52.00           44.00           53.00 //0.000010
  \             51.00           51.00           52.00           49.00           80.00           98.00
346743.00       635524.00       637278.00       634486.00       636627.00       638549.00
637034.00       348040.00           92.00           89.00           71.00           55.00
56.00           52.00           43.00 //0.000015
  \             46.00           60.00           59.00           72.00           75.00           82.00
86.00       201048.00       483809.00       613906.00       615567.00       483498.00       202567.00
```

```
101.00           77.00           70.00           53.00           58.00           52.00           47.00
38.00 //0.000020
  \              48.00           41.00           50.00           67.00           70.00           72.00
101.00           77.00          100.00          109.00           80.00           94.00           86.00
81.00           77.00           75.00           44.00           53.00           47.00           29.00
39.00 //0.000025
  \              42.00           35.00           57.00           54.00           54.00           62.00
70.00           73.00           74.00           85.00           81.00           91.00           66.00
66.00           56.00           75.00           51.00           57.00           49.00           46.00
35.00 //0.000030
  \              43.00           52.00           53.00           50.00           47.00           48.00
57.00           46.00           65.00           58.00           68.00           55.00           53.00
61.00           49.00           45.00           45.00           38.00           46.00           35.00
23.00 //0.000035
  \              33.00           42.00           47.00           38.00           56.00           54.00
55.00           44.00           55.00           41.00           55.00           55.00           65.00
65.00           58.00           49.00           43.00           47.00           47.00           41.00
31.00 //0.000040
  \              38.00           43.00           39.00           46.00           48.00           45.00
54.00           56.00           54.00           53.00           55.00           44.00           42.00
54.00           41.00           43.00           42.00           28.00           30.00           44.00
33.00 //0.000045
  \              33.00           32.00           36.00           48.00           47.00           41.00
44.00           45.00           42.00           46.00           54.00           44.00           48.00
45.00           59.00           36.00           37.00           50.00           28.00           29.00
31.00 //0.000050

Map //define a photon density map
  id "x-y pos of beam downstream of scattering medium" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 1.0100010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 1.0100010  //point 1
  p2 -1.0000000 -1.0000000 1.0100010  //point 2
  p3 1.0000000 -1.0000000 1.0100010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data           65.00           64.00           78.00           79.00           70.00           80.00
69.00           61.00           63.00           79.00           68.00           89.00           54.00
71.00           79.00           86.00           74.00           57.00           64.00           77.00
66.00 //-0.000050
  \              67.00           78.00           76.00           94.00           73.00           72.00
80.00           83.00          112.00           80.00           84.00           73.00           61.00
66.00           84.00           70.00           75.00           62.00           74.00           62.00
66.00 //-0.000045
  \              73.00           67.00           66.00           79.00           74.00           80.00
84.00           75.00           87.00           94.00           97.00           87.00           82.00
83.00           87.00           76.00           62.00           87.00           82.00           69.00
69.00 //-0.000040
  \              63.00           76.00           69.00           94.00           88.00           80.00
102.00          100.00           99.00           93.00          115.00           96.00           90.00
89.00           96.00           77.00           64.00           75.00           61.00           78.00
68.00 //-0.000035
  \              71.00           55.00           70.00           82.00           83.00           89.00
98.00          103.00          110.00          108.00          110.00           98.00          102.00
92.00           95.00           76.00           74.00           64.00           84.00           75.00
64.00 //-0.000030
  \              81.00           80.00           66.00           97.00           93.00           82.00
96.00          330.00          617.00          756.00          725.00          583.00          324.00
116.00          94.00           90.00           78.00           67.00           75.00           84.00
74.00 //-0.000025
  \              68.00           71.00           62.00           81.00           85.00           95.00
476.00          790.00          731.00          770.00          776.00          833.00          774.00
449.00          93.00           100.00           99.00           98.00           82.00           75.00
73.00 //-0.000020
  \              88.00           83.00           83.00           89.00           97.00          317.00
768.00          814.00          769.00          810.00          777.00          790.00          782.00
773.00          323.00           99.00           92.00           95.00           77.00           79.00
89.00 //-0.000015
  \              77.00           86.00           95.00           96.00          110.00          586.00
788.00          772.00          811.00          816.00          827.00          804.00          786.00
725.00          628.00          107.00           81.00           74.00           79.00           87.00
67.00 //-0.000010
  \              85.00           77.00           88.00          105.00           91.00          765.00
805.00          811.00          818.00          840.00          829.00          771.00          805.00
783.00          738.00          114.00           97.00           96.00           90.00           96.00
83.00 //-0.000005
  \              91.00           76.00           85.00          103.00           93.00          739.00
734.00          797.00          800.00          780.00          797.00          762.00          775.00
756.00          764.00           91.00          104.00           77.00           79.00           90.00
71.00 //0.000000
```

```
  \              72.00          76.00          84.00         101.00         102.00         621.00
799.00          806.00         771.00         810.00         847.00         776.00         773.00
782.00          613.00          97.00          91.00         100.00          85.00          76.00
86.00 //0.000005
  \              81.00          83.00          74.00          97.00         128.00         318.00
786.00          720.00         734.00         804.00         720.00         809.00         754.00
780.00          329.00          91.00          86.00          95.00          78.00          80.00
72.00 //0.000010
  \              82.00          65.00          90.00          89.00          77.00         109.00
450.00          803.00         798.00         796.00         755.00         766.00         773.00
518.00           94.00         112.00          95.00          85.00          85.00          73.00
65.00 //0.000015
  \              67.00          75.00          76.00          83.00          80.00         106.00
109.00          329.00         596.00         728.00         747.00         635.00         292.00
98.00           75.00          82.00          94.00          87.00          67.00          72.00
83.00 //0.000020
  \              68.00          63.00          67.00          95.00          83.00          92.00
93.00           89.00          92.00         104.00         105.00          93.00         113.00
103.00           90.00          82.00          86.00          89.00          60.00          68.00
61.00 //0.000025
  \              83.00          67.00          69.00          64.00          96.00          84.00
98.00           87.00          94.00          88.00         105.00         109.00         106.00
87.00           93.00          90.00          73.00          70.00          70.00          69.00
59.00 //0.000030
  \              75.00          72.00          89.00          92.00          78.00          98.00
88.00           88.00          89.00          91.00          98.00          83.00          91.00
92.00           78.00          78.00          85.00          94.00          87.00          74.00
71.00 //0.000035
  \              78.00          81.00          59.00          85.00          78.00          73.00
79.00           75.00          78.00          66.00          84.00          83.00          72.00
91.00           59.00          68.00          68.00          60.00          87.00          76.00
83.00 //0.000040
  \              55.00          59.00          71.00          58.00          79.00          79.00
65.00          100.00          75.00          81.00          71.00          96.00          80.00
78.00           89.00          71.00          73.00          75.00          78.00          76.00
74.00 //0.000045
  \              67.00          58.00          56.00          75.00          75.00          60.00
83.00           79.00          55.00          66.00          80.00          75.00          68.00
75.00           78.00          72.00          73.00          83.00          68.00          65.00
76.00 //0.000050
```

Appendix H – Test Case 4 Input File

Comparison of Quasi-Ballistic to Ballistic Photons for a Single Scattering Medium with a Collimating Hole

Input File testcase4.mci

```
RunInfo
  comment "Test Case 4"
  \       "Duplication of Chu and Pfeiffer Simulation Results"
  \       "to Determine Ratio of Quasi-Ballistic to Ballistic Photons"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 1000 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 0 //x, y, z coords of first point
  p1 1 -1 0 //x, y, z coords of second point
  p2 1 1 0 //x, y, z coords of third point
  p3 -1 1 0 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 .010001 //x, y, z coords of first point
  p1 1 -1 .010001 //x, y, z coords of second point
  p2 1 1 .010001 //x, y, z coords of third point
  p3 -1 1 .010001 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator hole medium" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 .010001 //x, y, z coords of first point
  p1 0 0.000025 .01 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0 0 0 //x, y, z coords of center in m
  p1 0 0.000025 0 //x, y, z coords of point on circumference in m
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 100000000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam upstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0100005 //x, y, z coords of first point
  p1 -1  1 .0100005 //x, y, z coords of second point
  p2 -1 -1 .0100005 //x, y, z coords of third point
  p3  1 -1 .0100005 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000050 +0.000050 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "scattercount vs radial position wrt source downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRSOURCE 0 0.000050 0.000005 //hash lookup, radial position wrt
source
```

```
  idxrow "row index1" hash PHOTSCATTERCOUNT 0 50 1 //hash lookup, scattercount

Map //define a density map
  id "scattercount vs radial position wrt start pos downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRSTART 0 0.000050 0.000005 //hash lookup, radial position wrt start
  idxrow "row index1" hash PHOTSCATTERCOUNT 0 50 1 //hash lookup, scattercount

Map //define a density map
  id "max radial deviation wrt source vs. max radial deviation wrt start pos downstream of collimating
hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 .0200015 //x, y, z coords of first point
  p1 -1  1 .0200015 //x, y, z coords of second point
  p2 -1 -1 .0200015 //x, y, z coords of third point
  p3  1 -1 .0200015 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSRMAXSOURCE 0 0.000050 0.000005 //hash lookup, max radial position
wrt source
  idxrow "row index1" hash PHOTPOSRMAXSTART 0 0.000050 0.000005 //hash lookup, max radial position wrt
start
```

Appendix I – Test Case 4 Output File

Comparison of Quasi-Ballistic to Ballistic Photons for a Single Scattering Medium with a Collimating Hole

Output File testcase4.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 4"
  comment1 "Duplication of Chu and Pfeiffer Simulation Results"
  comment2 "to Determine Ratio of Quasi-Ballistic to Ballistic Photons"
  comment3 ""
  programdescription "Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase4.mci" //name of input file for this run
  outputfile "testcase4.mco" //name of output file for this run
  photonqty 100000000 //total number of photons in all sources
  runstart Mon Dec 23 20:59:32 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box medium 0" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.000000 -1001.000000 -1001.000000  //point 0 (center for circle)
  p1 1001.000000 -1001.000000 -1001.000000  //point 1
  p2 1001.000000 1001.000000 -1001.000000  //point 2
  p3 -1001.000000 1001.000000 -1001.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "test medium 0 (ambient)" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.000000 -1000.000000 -1000.000000  //point 0 (center for circle)
  p1 1000.000000 -1000.000000 -1000.000000  //point 1
  p2 1000.000000 1000.000000 -1000.000000  //point 2
  p3 -1000.000000 1000.000000 -1000.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 690.875478 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 1000.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 690.875478 //extinction coefficient (m^-1)
  //albedo 1.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.000000 -1.000000 0.000000  //point 0 (center for circle)
  p1 1.000000 -1.000000 0.000000  //point 1
  p2 1.000000 1.000000 0.000000  //point 2
  p3 -1.000000 1.000000 0.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 2993.329531 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
```

```
  //absorbratio 9996891514694.884766 //absorption ratio (absorbed to unabsorbed photons) in direction
of extrudelen
  //mut 2993.329531 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.000000 -1.000000 0.010001  //point 0 (center for circle)
  p1 1.000000 -1.000000 0.010001  //point 1
  p2 1.000000 1.000000 0.010001  //point 2
  p3 -1.000000 1.000000 0.010001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator hole medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.000000 0.000000 0.010001  //point 0 (center for circle)
  p1 0.000000 0.000025 0.010000  //point 1
  p2 0.000000 0.000000 0.000000  //point 2
  p3 0.000000 0.000000 0.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 100000000 //initial number of photons in source to launch
  //qtyleft 100000000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
  p0 0.000000 0.000000 0.000000  //point 0 (center for circle)
  p1 0.000000 0.000025 0.000000  //point 1
  p2 0.000000 0.000000 0.000000  //point 2
  p3 0.000000 0.000000 0.000000  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

RunInfo
  runend Tue Dec 24 14:15:28 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam upstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.000000 1.000000 0.010001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.010001  //point 1
  p2 -1.000000 -1.000000 0.010001  //point 2
  p3 1.000000 -1.000000 0.010001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data          136.00          154.00          126.00          142.00          142.00          174.00
147.00          155.00          154.00          162.00          167.00          186.00          133.00
147.00          128.00          123.00          139.00          170.00          137.00          120.00
149.00 //-0.000050
  \             151.00          129.00          121.00          153.00          139.00          147.00
173.00          166.00          155.00          184.00          173.00          147.00          161.00
154.00          149.00          135.00          154.00          146.00          146.00          132.00
169.00 //-0.000045
  \             146.00          136.00          153.00          151.00          176.00          168.00
196.00          174.00          156.00          181.00          170.00          175.00          172.00
187.00          145.00          130.00          183.00          151.00          144.00          144.00
141.00 //-0.000040
  \             162.00          124.00          173.00          164.00          192.00          179.00
159.00          202.00          191.00          211.00          206.00          208.00          171.00
193.00          166.00          160.00          161.00          169.00          145.00          152.00
137.00 //-0.000035
```

```
  \             112.00          151.00          149.00          164.00          191.00          166.00
213.00          207.00          210.00          213.00          211.00          198.00          172.00
184.00          161.00          174.00          175.00          163.00          175.00          150.00
143.00 //-0.000030
  \             165.00          151.00          153.00          179.00          197.00          207.00
218.00          589.00         1236.00         1489.00         1515.00         1242.00          655.00
221.00          187.00          187.00          155.00          159.00          159.00          154.00
149.00 //-0.000025
  \             187.00          152.00          159.00          188.00          222.00          205.00
951.00         1554.00         1609.00         1574.00         1571.00         1564.00         1515.00
903.00          210.00          221.00          185.00          171.00          180.00          138.00
141.00 //-0.000020
  \             156.00          151.00          164.00          189.00          199.00          659.00
1509.00         1652.00         1606.00         1496.00         1572.00         1611.00
1536.00         1544.00          697.00          200.00          181.00          186.00
162.00          146.00          165.00 //-0.000015
  \             153.00          162.00          184.00          207.00          185.00         1314.00
1536.00         1599.00         1636.00         1642.00         1626.00         1608.00
1610.00         1478.00         1267.00          230.00          249.00          182.00
157.00          144.00          170.00 //-0.000010
  \             148.00          143.00          184.00          194.00          243.00         1506.00
1595.00         1567.00         1590.00         1578.00         1590.00         1547.00
1608.00         1566.00         1458.00          236.00          189.00          143.00
160.00          168.00          139.00 //-0.000005
  \             185.00          155.00          174.00          191.00          235.00         1532.00
1509.00         1526.00         1562.00         1519.00         1606.00         1557.00
1572.00         1559.00         1419.00          239.00          199.00          172.00
165.00          158.00          144.00 //0.000000
  \             136.00          146.00          183.00          196.00          228.00         1245.00
1514.00         1518.00         1499.00         1561.00         1593.00         1510.00
1614.00         1608.00         1271.00          222.00          186.00          178.00
177.00          170.00          144.00 //0.000005
  \             152.00          146.00          183.00          171.00          234.00          614.00
1591.00         1599.00         1526.00         1611.00         1571.00         1588.00
1545.00         1574.00          596.00          187.00          173.00          190.00
132.00          147.00          138.00 //0.000010
  \             174.00          175.00          168.00          169.00          216.00          202.00
930.00         1608.00         1581.00         1631.00         1620.00         1477.00         1548.00
1000.00          247.00          217.00          170.00          149.00          152.00
149.00          140.00 //0.000015
  \             156.00          152.00          156.00          181.00          168.00          220.00
218.00          633.00         1160.00         1486.00         1435.00         1221.00          622.00
212.00          224.00          192.00          172.00          179.00          156.00          160.00
127.00 //0.000020
  \             168.00          152.00          156.00          161.00          189.00          190.00
197.00          195.00          208.00          217.00          235.00          216.00          210.00
186.00          177.00          181.00          175.00          140.00          124.00          150.00
144.00 //0.000025
  \             141.00          153.00          153.00          143.00          149.00          164.00
178.00          203.00          188.00          187.00          201.00          176.00          163.00
180.00          176.00          173.00          151.00          143.00          156.00          157.00
137.00 //0.000030
  \             136.00          132.00          153.00          151.00          140.00          153.00
166.00          170.00          179.00          170.00          164.00          194.00          161.00
174.00          155.00          144.00          142.00          178.00          121.00          141.00
128.00 //0.000035
  \             144.00          163.00          148.00          162.00          136.00          160.00
172.00          160.00          167.00          166.00          174.00          162.00          162.00
171.00          152.00          144.00          138.00          148.00          153.00          150.00
151.00 //0.000040
  \             126.00          149.00          133.00          143.00          159.00          149.00
140.00          159.00          174.00          153.00          168.00          132.00          128.00
158.00          147.00          157.00          132.00          141.00          138.00          145.00
126.00 //0.000045
  \             130.00          114.00          127.00          139.00          149.00          145.00
157.00          139.00          181.00          165.00          151.00          140.00          164.00
145.00          144.00          142.00          142.00          127.00          127.00          121.00
139.00 //0.000050

Map //define a photon density map
  id "x-y pos of beam downstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.000000 1.000000 0.020001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.020001  //point 1
  p2 -1.000000 -1.000000 0.020001  //point 2
  p3 1.000000 -1.000000 0.020001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000050 0.000050 0.000005 //column index
  //         -0.000050       -0.000045       -0.000040       -0.000035       -0.000030       -0.000025
-0.000020       -0.000015       -0.000010       -0.000005        0.000000        0.000005
0.000010        0.000015        0.000020        0.000025        0.000030        0.000035
0.000040        0.000045        0.000050
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
```

```
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000050
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000045
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000040
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000035
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           1.00           0.00           0.00
1.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000030
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00          364.00         983.00        1219.00        1261.00         989.00         420.00
1.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000025
  \               0.00           0.00           0.00           0.00           0.00           0.00
737.00        1297.00        1301.00        1304.00        1286.00        1271.00        1252.00
658.00          0.00           0.00           0.00           0.00           0.00           0.00
0.00 //-0.000020
  \               0.00           0.00           0.00           0.00           0.00         419.00
1268.00       1350.00        1310.00        1197.00        1281.00        1281.00
1231.00       1264.00         441.00           0.00           0.00           0.00
0.00          0.00          0.00 //-0.000015
  \               0.00           0.00           0.00           0.00           0.00        1021.00
1238.00       1296.00        1299.00        1311.00        1297.00        1296.00
1316.00       1215.00        1009.00           0.00           0.00           0.00
0.00          0.00          0.00 //-0.000010
  \               0.00           0.00           0.00           0.00           1.00        1268.00
1317.00       1269.00        1268.00        1253.00        1276.00        1246.00
1276.00       1290.00        1198.00           0.00           0.00           0.00
0.00          0.00          0.00 //-0.000005
  \               0.00           0.00           0.00           0.00           1.00        1260.00
1234.00       1230.00        1213.00        1211.00        1296.00        1273.00
1303.00       1269.00        1183.00           1.00           0.00           0.00
0.00          0.00          0.00 //0.000000
  \               0.00           0.00           0.00           0.00           0.00         979.00
1244.00       1221.00        1180.00        1271.00        1260.00        1208.00
1318.00       1296.00         961.00           0.00           0.00           0.00
0.00          0.00          0.00 //0.000005
  \               0.00           0.00           0.00           0.00           0.00         396.00
1289.00       1317.00        1238.00        1297.00        1267.00        1284.00
1258.00       1304.00         377.00           0.00           0.00           0.00
0.00          0.00          0.00 //0.000010
  \               0.00           0.00           0.00           0.00           0.00           1.00
673.00        1341.00        1284.00        1349.00        1322.00        1209.00        1281.00
723.00          0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000015
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00          410.00         939.00        1226.00        1199.00         924.00         371.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000020
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000025
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000030
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000035
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000040
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000045
  \               0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00            0.00           0.00           0.00           0.00           0.00           0.00
0.00 //0.000050

Map //define a photon density map
  id "scattercount vs radial position wrt source downstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
```

```
  p0 1.000000 1.000000 0.020001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.020001  //point 1
  p2 -1.000000 -1.000000 0.020001  //point 2
  p3 1.000000 -1.000000 0.020001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTSCATTERCOUNT 0.000000 50.000000 1.000000 //row index
  idxcol "col index1" HASH PHOTPOSRSOURCE 0.000000 0.000050 0.000005 //column index
  //          0.000000        0.000005        0.000010        0.000015        0.000020        0.000025
0.000030        0.000035        0.000040        0.000045        0.000050
  data         4007.00        11867.00        19872.00        28263.00        35906.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000000
  \               0.00            13.00           12.00           22.00           48.00           12.00
1.00            0.00            0.00            0.00            0.00 //1.000000
  \               0.00            4.00            1.00            3.00            4.00            0.00
0.00            0.00            0.00            0.00            0.00 //2.000000
  \               0.00            0.00            0.00            1.00            1.00            0.00
0.00            0.00            0.00            0.00            0.00 //3.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //4.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //5.000000
  \               0.00            0.00            0.00            0.00            1.00            0.00
0.00            0.00            0.00            0.00            0.00 //6.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //7.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //8.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //9.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //10.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //11.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //12.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //13.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //14.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //15.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //16.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //17.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //18.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //19.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //20.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //21.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //22.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //23.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //24.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //25.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //26.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //27.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //28.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //29.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //30.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //31.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //32.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //33.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //34.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //35.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //36.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //37.000000
```

```
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //38.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //39.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //40.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //41.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //42.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //43.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //44.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //45.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //46.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //47.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //48.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //49.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //50.000000

Map //define a photon density map
  id "scattercount vs radial position wrt start pos downstream of collimating hole" //id of density
map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.000000 1.000000 0.020001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.020001  //point 1
  p2 -1.000000 -1.000000 0.020001  //point 2
  p3 1.000000 -1.000000 0.020001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTSCATTERCOUNT 0.000000 50.000000 1.000000 //row index
  idxcol "col index1" HASH PHOTPOSRSTART 0.000000 0.000050 0.000005 //column index
  //          0.000000        0.000005        0.000010        0.000015        0.000020        0.000025
0.000030        0.000035        0.000040        0.000045        0.000050
  data        99915.00          0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000000
  \              4.00            5.00            21.00           7.00           16.00           17.00
13.00           14.00            6.00            5.00            0.00 //1.000000
  \              1.00            1.00            1.00            0.00            4.00            2.00
2.00            0.00            1.00            0.00            0.00 //2.000000
  \              0.00            0.00            0.00            0.00            1.00            0.00
1.00            0.00            0.00            0.00            0.00 //3.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //4.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //5.000000
  \              0.00            0.00            1.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //6.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //7.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //8.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //9.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //10.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //11.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //12.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //13.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //14.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //15.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //16.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //17.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //18.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //19.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //20.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //21.000000
```

```
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //22.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //23.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //24.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //25.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //26.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //27.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //28.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //29.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //30.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //31.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //32.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //33.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //34.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //35.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //36.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //37.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //38.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //39.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //40.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //41.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //42.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //43.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //44.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //45.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //46.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //47.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //48.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //49.000000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //50.000000

Map //define a photon density map
  id "max radial deviation wrt source vs. max radial deviation wrt start pos downstream of collimating
hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.000000 1.000000 0.020001  //point 0 (center for circle)
  p1 -1.000000 1.000000 0.020001  //point 1
  p2 -1.000000 -1.000000 0.020001  //point 2
  p3 1.000000 -1.000000 0.020001  //point 3
  normalvector 0.000000 0.000000 1.000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSRMAXSTART 0.000000 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSRMAXSOURCE 0.000000 0.000050 0.000005 //column index
  //          0.000000        0.000005        0.000010        0.000015        0.000020        0.000025
0.000030        0.000035        0.000040        0.000045        0.000050
  data         4007.00        11868.00        19872.00        28264.00        35908.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000000
  \              0.00            0.00            3.00            1.00            2.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000005
  \              0.00            0.00            2.00            9.00           10.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000010
  \              0.00            0.00            1.00            1.00            4.00            2.00
0.00            0.00            0.00            0.00            0.00 //0.000015
  \              0.00            0.00            1.00            7.00           11.00            1.00
0.00            0.00            0.00            0.00            0.00 //0.000020
  \              0.00            0.00            0.00            5.00           12.00            3.00
0.00            0.00            0.00            0.00            0.00 //0.000025
```

```
  \             0.00          0.00          0.00          3.00          10.00          3.00
0.00          0.00          1.00          0.00          0.00 //0.000030
  \             0.00          0.00          0.00          0.00          13.00          1.00
0.00          0.00          0.00          0.00          0.00 //0.000035
  \             0.00          0.00          0.00          0.00           3.00          4.00
0.00          0.00          0.00          0.00          0.00 //0.000040
  \             0.00          0.00          0.00          0.00           1.00          3.00
1.00          0.00          0.00          0.00          0.00 //0.000045
  \             0.00          0.00          0.00          0.00           0.00          0.00
0.00          0.00          0.00          0.00          0.00 //0.000050
```

Appendix J – Test Case 5 Input File

A Point Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

Input File testcase5.mci

```
RunInfo
  comment "Test Case 5"
  \       "Point source with two 45 deg. mirrors, 10 x beam expander, 0.2 mm slit, and three
collimating holes"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "mirror 1" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.10 0 9.5 //x, y, z coords of first point
  p1 0.10 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector 1 0 1 //normal vector for extrude

Medium //define a scattering and absorbing medium
  id "mirror 2" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 9.5 //x, y, z coords of first point
  p1 0 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector -1 0 -1 //normal vector for extrude

Medium //define a scattering and absorbing medium
  id "diverging lens 1" //glass part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1.45 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10 //x, y, z coords of first point
  p1 0 0.015 10 //x, y, z coords of second point
  normalvector 0 0 1 //normal vector for extrude
  extrudelen  0.004 //extrusion length of cylinder

Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "diverging lens 2" //air part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 10.012 //x, y, z coords of first point
  p1 0 0.01125 10.012 //x, y, z coords of second point
  p3 0 0 10.004 //x, y, z coords of fourth point (cutting plane)
  normalvector 0 0 1 //normal vector of cut surface (plano side on right)

Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "converging lens"
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 2 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 9.9755 //x, y, z coords of first point
  p1 0 0.2485 9.9755 //x, y, z coords of second point
  p3 0 0 10.2235 //x, y, z coords of fourth point
  normalvector 0 0 -1 //normal vector of cut surface (plano side on left)

Medium //define a scattering and absorbing medium
  id "slit blocking medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.25 //x, y, z coords of first point
  p1 1 -1 10.25 //x, y, z coords of second point
  p2 1 1 10.25 //x, y, z coords of third point
  p3 -1 1 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "slit opening medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
```

```
  shptype RECTANGLE //shape of medium
  p0 -.01 -.0001 10.25 //x, y, z coords of first point
  p1 .01 -.0001 10.25 //x, y, z coords of second point
  p2 .01 .0001 10.25 //x, y, z coords of third point
  p3 -.01 .0001 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1.4 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -.02 -.02 10.251 //x, y, z coords of first point
  p1 .02 -.02 10.251 //x, y, z coords of second point
  p2 .02 .02 10.251 //x, y, z coords of third point
  p3 -.02 .02 10.251 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.261 //x, y, z coords of first point
  p1 1 -1 10.261 //x, y, z coords of second point
  p2 1 1 10.261 //x, y, z coords of third point
  p3 -1 1 10.261 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator hole 1" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 -0.000100 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 2" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 3" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.000100 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

PhotonSource //define a photon source
  id "point source 1"
  type POINT //point type of photon source
  p0 0.10 0 0  //x, y, z coords of center in cm
  p0 0.10 .000002 0  //x, y, z coords of center in cm
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam before expansion"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 9.9 //x, y, z coords of first point
  p1 -1  1 9.9 //x, y, z coords of second point
  p2 -1 -1 9.9 //x, y, z coords of third point
  p3  1 -1 9.9 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
```

```
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam after expansion"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.249 //x, y, z coords of first point
  p1 -1  1 10.249 //x, y, z coords of second point
  p2 -1 -1 10.249 //x, y, z coords of third point
  p3  1 -1 10.249 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam upstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.261 //x, y, z coords of first point
  p1 -1  1 10.261 //x, y, z coords of second point
  p2 -1 -1 10.261 //x, y, z coords of third point
  p3  1 -1 10.261 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

Map //define a density map
  id "x-y pos downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.271001 //x, y, z coords of first point
  p1 -1  1 10.271001 //x, y, z coords of second point
  p2 -1 -1 10.271001 //x, y, z coords of third point
  p3  1 -1 10.271001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000150 +0.000150 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos

Map //define a density map
  id "photon info downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.271001 //x, y, z coords of first point
  p1 -1  1 10.271001 //x, y, z coords of second point
  p2 -1 -1 10.271001 //x, y, z coords of third point
  p3  1 -1 10.271001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTINFO 0 20 1 //hash lookup, movecount
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

Appendix K – Test Case 5 Output File

A Point Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

Output File testcase5.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 5"
  comment1 "Point source with two 45 deg. mirrors, 10 x beam expander, 0.2 mm slit, and three
collimating holes"
  comment2 ""
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase5.mci" //name of input file for this run
  outputfile "testcase5.mco" //name of output file for this run
  photonqty 1 //total number of photons in all sources
  runstart Sat Dec 28 13:27:54 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.0000000 -1001.0000000 -1001.0000000  //point 0 (center for circle)
  p1 1001.0000000 -1001.0000000 -1001.0000000  //point 1
  p2 1001.0000000 1001.0000000 -1001.0000000  //point 2
  p3 -1001.0000000 1001.0000000 -1001.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "ambient" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.0000000 -1000.0000000 -1000.0000000  //point 0 (center for circle)
  p1 1000.0000000 -1000.0000000 -1000.0000000  //point 1
  p2 1000.0000000 1000.0000000 -1000.0000000  //point 2
  p3 -1000.0000000 1000.0000000 -1000.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "mirror 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 8059.047876 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 10000000.004464 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 8059.047876 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 10000.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.1000000 0.0000000 9.5000000  //point 0 (center for circle)
  p1 0.1000000 0.0150000 9.5000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.7071068 0.0000000 0.7071068  //surface normal
  extrudelen 0.002000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "mirror 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 8059.047876 //coefficient of absorption (m^-1)
```

```
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 10000000.004464 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 8059.047876 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 10000.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 9.5000000  //point 0 (center for circle)
  p1 0.0000000 0.0150000 9.5000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector -0.7071068 0.0000000 -0.7071068  //surface normal
  extrudelen 0.002000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "diverging lens 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.450000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 10.0000000  //point 0 (center for circle)
  p1 0.0000000 0.0150000 10.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.004000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "diverging lens 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype SEMISPHERE //type of shape for object
  p0 0.0000000 0.0000000 10.0120000  //point 0 (center for circle)
  p1 0.0000000 0.0112500 10.0120000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 10.0040000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.011250 //radius of circle (m)
  //radius squared 0.000127 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "converging lens" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 2.000000 //index of refraction
  shptype SEMISPHERE //type of shape for object
  p0 0.0000000 0.0000000 9.9755000  //point 0 (center for circle)
  p1 0.0000000 0.2485000 9.9755000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 10.2235000  //point 3
  normalvector 0.0000000 0.0000000 -1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.248500 //radius of circle (m)
  //radius squared 0.061752 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "slit blocking medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
```

```
  mua 59866.590624 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9996891514694.884766 //absorption ratio (absorbed to unabsorbed photons) in direction
of extrudelen
  //mut 59866.590624 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 10.2500000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 10.2500000  //point 1
  p2 1.0000000 1.0000000 10.2500000  //point 2
  p3 -1.0000000 1.0000000 10.2500000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000500 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "slit opening medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -0.0100000 -0.0001000 10.2500000  //point 0 (center for circle)
  p1 0.0100000 -0.0001000 10.2500000  //point 1
  p2 0.0100000 0.0001000 10.2500000  //point 2
  p3 -0.0100000 0.0001000 10.2500000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000500 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.400000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -0.0200000 -0.0200000 10.2510000  //point 0 (center for circle)
  p1 0.0200000 -0.0200000 10.2510000  //point 1
  p2 0.0200000 0.0200000 10.2510000  //point 2
  p3 -0.0200000 0.0200000 10.2510000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 2993.329531 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9996891514694.884766 //absorption ratio (absorbed to unabsorbed photons) in direction
of extrudelen
  //mut 2993.329531 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 10.2610000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 10.2610000  //point 1
  p2 1.0000000 1.0000000 10.2610000  //point 2
  p3 -1.0000000 1.0000000 10.2610000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator hole 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
```

```
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 -0.0001000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000103 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "collimator hole 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "collimator hole 3" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0001000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000103 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

PhotonSource //define a photon source
  id "point source 1" //id of photon source
  type POINT //type of photon source
  qty 1 //initial number of photons in source to launch
  //qtyleft 1 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
  p0 0.1000000 0.0000020 0.0000000  //point 0 (center for circle)
  p1 0.1000000 0.0000020 0.0000000  //point 1
  p2 0.1000000 0.0000020 0.0000000  //point 2
  p3 0.1000000 0.0000020 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.000000 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

PhotonInfo //photon information
  posstart 0.1000000 0.0000020 0.0000000  //starting position
  trajstart 0.0000000 0.0000000 1.0000000  //starting trajectory
  poscurrent -0.0000000 0.0000198 10.2710010  //current position
  trajcurrent -0.0000000 0.0000002 1.0000000  //current trajectory
  medium ambient //current medium in which photon resides
  wavelength 514.000000 //wavelength of photon (nm)
  movecount 12 //number of moves made by photon
  scattercount 0 //number of scatter events
  reflectcount 2 //number of reflect events
  refractcount 10 //number of refract events
  pathlength 10.371001 //total pathlength (m)
  life 0.000000034610 //lifetime of photon (secs)
  desireddist 10000000000000000000.000000 //current desired distance
```

```
  photposrsource 0.100000 //radial component of current position (reference to the photon source
normal)
  photposrstart 0.100000 //radial component of current position (reference to the photon start
trajectory and pos)
  phottrajdotsource 1.000000 //dot product of current trajectory and photon source (cosine of forward
scattering angle for photons with starting trajectory equal to source normal)
  phottrajdotstart 1.000000 //dot product of current trajectory and photon starting trajectory (cosine
of forward scattering angle)
  photposrmaxsource 0.100000 //maximum radial component of any recorded position (reference to the
photon source normal)
  photposrmaxstart 0.100000 //maximum radial component of any recorded position (reference to the
photon start trajectory and pos)
  poslist 0.1000000 0.0000020 0.0000000  //starting position
  \       0.1000000 0.0000020 9.5000000
  \       -0.0000000 0.0000020 9.5000000
  \       -0.0000000 0.0000020 10.0000000
  \       -0.0000000 0.0000020 10.0007500
  \       -0.0000000 0.0000023 10.0040000
  \       -0.0000000 0.0000198 10.2235000
  \       -0.0000000 0.0000198 10.2240000
  \       -0.0000000 0.0000198 10.2500000
  \       -0.0000000 0.0000198 10.2505000
  \       -0.0000000 0.0000198 10.2510000
  \       -0.0000000 0.0000198 10.2610000
  \       -0.0000000 0.0000198 10.2710000  //last recorded position

RunInfo
  runend Sat Dec 28 13:27:54 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam before expansion" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 9.9000000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 9.9000000  //point 1
  p2 -1.0000000 -1.0000000 9.9000000  //point 2
  p3 1.0000000 -1.0000000 9.9000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
  //         -0.012500       -0.012000       -0.011500       -0.011000       -0.010500       -0.010000
-0.009500       -0.009000       -0.008500       -0.008000       -0.007500       -0.007000       -
0.006500       -0.006000       -0.005500       -0.005000       -0.004500       -0.004000       -
0.003500       -0.003000       -0.002500       -0.002000       -0.001500       -0.001000       -
0.000500       -0.000000        0.000500        0.001000        0.001500        0.002000
0.002500        0.003000        0.003500        0.004000        0.004500        0.005000
0.005500        0.006000        0.006500        0.007000        0.007500        0.008000
0.008500        0.009000        0.009500        0.010000        0.010500        0.011000
0.011500        0.012000        0.012500
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.011000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.009500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.009000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.008500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.008000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.007500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.007000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.006500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.006000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.005500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.004000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.003500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.003000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.002500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.002000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.001500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.001000
  \             0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.000500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          1.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.000000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.000500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.001000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.001500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.002000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.002500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.003000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.003500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.004000
  \             0.00          0.00            0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00 //0.004500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.005000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.005500
  \             0.00          0.00            0.00          0.00          0.00          0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.006000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.006500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.007000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.007500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011000
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  \              0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011500
  \              0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012000
  \              0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012500

Map //define a photon density map
  id "x-y pos of beam after expansion" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2490000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2490000  //point 1
  p2 -1.0000000 -1.0000000 10.2490000  //point 2
  p3 1.0000000 -1.0000000 10.2490000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
  //         -0.012500       -0.012000       -0.011500       -0.011000       -0.010500       -0.010000
-0.009500       -0.009000       -0.008500       -0.008000       -0.007500       -0.007000       -
0.006500       -0.006000       -0.005500       -0.005000       -0.004500       -0.004000       -
0.003500       -0.003000       -0.002500       -0.002000       -0.001500       -0.001000       -
0.000500       -0.000000        0.000500        0.001000        0.001500        0.002000
0.002500        0.003000        0.003500        0.004000        0.004500        0.005000
0.005500        0.006000        0.006500        0.007000        0.007500        0.008000
0.008500        0.009000        0.009500        0.010000        0.010500        0.011000
0.011500        0.012000        0.012500
  data           0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012500
  \              0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //-0.012000
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0.00            0.00            0.00 //-0.011500
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0.00            0.00            0.00 //-0.011000
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0.00            0.00            0.00 //0.007500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012500

Map //define a photon density map
  id "x-y pos of beam upstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2610000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2610000  //point 1
  p2 -1.0000000 -1.0000000 10.2610000  //point 2
  p3 1.0000000 -1.0000000 10.2610000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
  //         -0.012500       -0.012000       -0.011500       -0.011000       -0.010500       -0.010000
-0.009500       -0.009000       -0.008500       -0.008000       -0.007500       -0.007000       -
0.006500       -0.006000       -0.005500       -0.005000       -0.004500       -0.004000       -
0.003500       -0.003000       -0.002500       -0.002000       -0.001500       -0.001000       -
0.000500       -0.000000        0.000500        0.001000        0.001500        0.002000
0.002500        0.003000        0.003500        0.004000        0.004500        0.005000
0.005500        0.006000        0.006500        0.007000        0.007500        0.008000
0.008500        0.009000        0.009500        0.010000        0.010500        0.011000
0.011500        0.012000        0.012500
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //-0.011000
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.009500
  \             0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00 //-0.009000
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0.00          0.00          0.00 //-0.008500
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0.00          0.00          0.00 //-0.008000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.007500
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0.00          0.00          0.00 //-0.007000
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0.00          0.00          0.00 //-0.006000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.005500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.004000
  \             0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00 //-0.003500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.003000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.002500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.002000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.001500
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.000500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          1.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //-0.000000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.000500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.001000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.001500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.002000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.002500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.003000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.003500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.004000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.004500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.005000
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.005500
  \             0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.006000
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  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.006500
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.007000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.007500
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008500
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.009500
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.010500
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012500

Map //define a photon density map
  id "x-y pos downstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2710010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2710010  //point 1
  p2 -1.0000000 -1.0000000 10.2710010  //point 2
  p3 1.0000000 -1.0000000 10.2710010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000150 0.000150 0.000005 //column index
  //         -0.000150       -0.000145       -0.000140       -0.000135       -0.000130       -0.000125
-0.000120       -0.000115       -0.000110       -0.000105       -0.000100       -0.000095       -
0.000090       -0.000085       -0.000080       -0.000075       -0.000070       -0.000065       -
0.000060       -0.000055       -0.000050       -0.000045       -0.000040       -0.000035       -
0.000030       -0.000025       -0.000020       -0.000015       -0.000010       -0.000005
0.000000        0.000005        0.000010        0.000015        0.000020        0.000025
0.000030        0.000035        0.000040        0.000045        0.000050        0.000055
0.000060        0.000065        0.000070        0.000075        0.000080        0.000085
0.000090        0.000095        0.000100        0.000105        0.000110        0.000115
0.000120        0.000125        0.000130        0.000135        0.000140        0.000145
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000050
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000030
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  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //-0.000025
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //-0.000020
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //-0.000015
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //-0.000010
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //-0.000005
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //0.000000
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //0.000005
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //0.000010
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            1.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00 //0.000015
  \             0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
```

```
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000020
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000030
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000050

Map //define a photon density map
  id "photon info downstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2710010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2710010  //point 1
  p2 -1.0000000 -1.0000000 10.2710010  //point 2
  p3 1.0000000 -1.0000000 10.2710010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTINFO 0.000000 20.000000 1.000000 //column index
  //          0.000000        1.000000        2.000000        3.000000        4.000000        5.000000
6.000000        7.000000        8.000000        9.000000       10.000000       11.000000
12.000000       13.000000       14.000000       15.000000       16.000000       17.000000
18.000000       19.000000       20.000000
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000050
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000040
```

```
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000030
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000020
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000015
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000010
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //-0.000005
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000005
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000010
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            1.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000015
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000020
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000030
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00 //0.000050
```

Appendix L – Test Case 6 Input File

A Uniform Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

Input File testcase6.mci

```
RunInfo
  comment "Test Case 6"
  \       "Uniform source with two 45 deg. mirrors, 10 x beam expander, 0.2 mm slit, and three
collimating holes"

#include "stdsetup.mci" //include the standard setup for all test cases (random number generator and
bounding box)

Medium //define a scattering and absorbing medium
  id "mirror 1" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.10 0 9.5 //x, y, z coords of first point
  p1 0.10 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector 1 0 1 //normal vector for extrude

Medium //define a scattering and absorbing medium
  id "mirror 2" //first mirror
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000 //absorb ratio
  indexrefraction 10000 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 9.5 //x, y, z coords of first point
  p1 0 0.015 9.5 //x, y, z coords of second point
  extrudelen 0.002 //extrude length
  normalvector -1 0 -1 //normal vector for extrude

Medium //define a scattering and absorbing medium
  id "diverging lens 1" //glass part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.0 //coefficient of scattering
  mua 0.0 //coefficient of absorption
  indexrefraction 1.45 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10 //x, y, z coords of first point
  p1 0 0.015 10 //x, y, z coords of second point
  normalvector 0 0 1 //normal vector for extrude
  extrudelen  0.004 //extrusion length of cylinder

Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "diverging lens 2" //air part of diverging lens
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 10.012 //x, y, z coords of first point
  p1 0 0.01125 10.012 //x, y, z coords of second point
  p3 0 0 10.004 //x, y, z coords of fourth point (cutting plane)
  normalvector 0 0 1 //normal vector of cut surface (plano side on right)

Medium //define a scattering and absorbing medium (lens semisphere shape)
  id "converging lens"
  g 1.0 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 2 //index of refraction
  shptype SEMISPHERE //shape of medium
  p0 0 0 9.9755 //x, y, z coords of first point
  p1 0 0.2485 9.9755 //x, y, z coords of second point
  p3 0 0 10.2235 //x, y, z coords of fourth point
  normalvector 0 0 -1 //normal vector of cut surface (plano side on left)

Medium //define a scattering and absorbing medium
  id "slit blocking medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.25 //x, y, z coords of first point
  p1 1 -1 10.25 //x, y, z coords of second point
  p2 1 1 10.25 //x, y, z coords of third point
  p3 -1 1 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "slit opening medium" //blocking medium for slit upstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
```

```
  shptype RECTANGLE //shape of medium
  p0 -.01 -.0001 10.25 //x, y, z coords of first point
  p1 .01 -.0001 10.25 //x, y, z coords of second point
  p2 .01 .0001 10.25 //x, y, z coords of third point
  p3 -.01 .0001 10.25 //x, y, z coords of fourth point
  extrudelen .0005 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "scattering medium" //sample of scattering medium
  g .9 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1.4 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -.02 -.02 10.251 //x, y, z coords of first point
  p1 .02 -.02 10.251 //x, y, z coords of second point
  p2 .02 .02 10.251 //x, y, z coords of third point
  p3 -.02 .02 10.251 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //blocking medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 10000000000000 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype RECTANGLE //shape of medium
  p0 -1 -1 10.261 //x, y, z coords of first point
  p1 1 -1 10.261 //x, y, z coords of second point
  p2 1 1 10.261 //x, y, z coords of third point
  p3 -1 1 10.261 //x, y, z coords of fourth point
  extrudelen .01 //extrusion length of box

Medium //define a scattering and absorbing medium
  id "collimator hole 1" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 -0.000100 0 10.261 //x, y, z coords of first point
  p1 -0.000100 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 2" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0 0 10.261 //x, y, z coords of first point
  p1 0 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

Medium //define a scattering and absorbing medium
  id "collimator hole 3" //hole medium for collimator downstream of sample
  g 1 //g factor of medium (mean cosine of forward scattering angle)
  scatterratio 0 //scattering ratio
  absorbratio 0 //absorb ratio
  indexrefraction 1 //index of refraction
  shptype CIRCLE //shape of medium
  p0 0.000100 0 10.261 //x, y, z coords of first point
  p1 0.000100 0.000025 10.261 //x, y, z coords of second point
  normalvector 0 0 1 //direction of hole is in dir'n of and parallel to z-axis
  extrudelen .01 //extrusion length of hole

PhotonSource //define a photon source
  id "uniform source 1"
  type UNIFORM //uniform type of photon source
  p0 0.10 0 0 //x, y, z coords of center in cm
  p1 0.10 0.00125 0 //x, y, z coords of point on circumference in cm
  normalvector 0 0 1 //launch photons parallel to z axis
  wavelength 514 //wavelength in nm
  qty 1000000 //number of photons to launch from source

Map //define a density map
  id "x-y pos of beam before expansion"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 9.9 //x, y, z coords of first point
  p1 -1  1 9.9 //x, y, z coords of second point
  p2 -1 -1 9.9 //x, y, z coords of third point
  p3  1 -1 9.9 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
```

```
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

Map //define a density map
  id "x-y pos of beam after expansion"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.249 //x, y, z coords of first point
  p1 -1  1 10.249 //x, y, z coords of second point
  p2 -1 -1 10.249 //x, y, z coords of third point
  p3  1 -1 10.249 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

  Map //define a density map
  id "x-y pos of beam upstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.261 //x, y, z coords of first point
  p1 -1  1 10.261 //x, y, z coords of second point
  p2 -1 -1 10.261 //x, y, z coords of third point
  p3  1 -1 10.261 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.0125 +0.0125 0.0005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.0125 +0.0125 0.0005 //hash lookup, y pos

  Map //define a density map
  id "x-y pos downstream of collimating hole"
  type planar //planar type of map
  shptype RECTANGLE //shape of medium
  p0  1  1 10.271001 //x, y, z coords of first point
  p1 -1  1 10.271001 //x, y, z coords of second point
  p2 -1 -1 10.271001 //x, y, z coords of third point
  p3  1 -1 10.271001 //x, y, z coords of fourth point
  idxcol "col index1" hash PHOTPOSX -0.000150 +0.000150 0.000005 //hash lookup, x pos
  idxrow "row index1" hash PHOTPOSY -0.000050 +0.000050 0.000005 //hash lookup, y pos
```

Appendix M – Test Case 6 Output File

A Uniform Source with Two Mirrors, a Beam Expander, a Slit, a Single Medium, and an Array of Three Collimating Holes

Output File testcase6.mco

```
RunInfo //information on this simulation run
  comment0 "Test Case 6"
  comment1 "Uniform source with two 45 deg. mirrors, 10 x beam expander, 0.2 mm slit, and three
collimating holes"
  comment2 ""
  comment3 ""
  programdescription "Photon Transport Simulator: Monte Carlo Simulation of Photon Transport in Media"
  programname "pts1.exe (m1main04.c)"
  programauthor "Nick Pfeiffer"
  programversiondate "December 2002"
  inputfile "testcase6.mci" //name of input file for this run
  outputfile "testcase6.mco" //name of output file for this run
  photonqty 1000000 //total number of photons in all sources
  runstart Sat Dec 28 14:14:45 2002 //starting time and date of run

RandomNumberGenerator //define the random number generator
  type MC //type of random number generator
  seed 0.000000 //initial seed
  //count 0.000000 //quantity of numbers generated since initial seed

Medium //define a scattering and absorbing medium
  id "bounding box" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 100000000.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9.99999999999999967300000000000000000000000e+98 //absorption ratio (absorbed to
unabsorbed photons) in direction of extrudelen
  //mut 100000000.000000 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1001.0000000 -1001.0000000 -1001.0000000  //point 0 (center for circle)
  p1 1001.0000000 -1001.0000000 -1001.0000000  //point 1
  p2 1001.0000000 1001.0000000 -1001.0000000  //point 2
  p3 -1001.0000000 1001.0000000 -1001.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2002.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "ambient" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1000.0000000 -1000.0000000 -1000.0000000  //point 0 (center for circle)
  p1 1000.0000000 -1000.0000000 -1000.0000000  //point 1
  p2 1000.0000000 1000.0000000 -1000.0000000  //point 2
  p3 -1000.0000000 1000.0000000 -1000.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 2000.000000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "mirror 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 8059.047876 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 10000000.004464 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 8059.047876 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 10000.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.1000000 0.0000000 9.5000000  //point 0 (center for circle)
  p1 0.1000000 0.0150000 9.5000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.7071068 0.0000000 0.7071068  //surface normal
  extrudelen 0.002000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "mirror 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 8059.047876 //coefficient of absorption (m^-1)
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  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 10000000.004464 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 8059.047876 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 10000.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 9.5000000  //point 0 (center for circle)
  p1 0.0000000 0.0150000 9.5000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector -0.7071068 0.0000000 -0.7071068  //surface normal
  extrudelen 0.002000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "diverging lens 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.450000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 10.0000000  //point 0 (center for circle)
  p1 0.0000000 0.0150000 10.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.004000 //extrusion length (m) (0 if planar)
  //radius 0.015000 //radius of circle (m)
  //radius squared 0.000225 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "diverging lens 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype SEMISPHERE //type of shape for object
  p0 0.0000000 0.0000000 10.0120000  //point 0 (center for circle)
  p1 0.0000000 0.0112500 10.0120000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 10.0040000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.011250 //radius of circle (m)
  //radius squared 0.000127 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "converging lens" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 2.000000 //index of refraction
  shptype SEMISPHERE //type of shape for object
  p0 0.0000000 0.0000000 9.9755000  //point 0 (center for circle)
  p1 0.0000000 0.2485000 9.9755000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 10.2235000  //point 3
  normalvector 0.0000000 0.0000000 -1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.248500 //radius of circle (m)
  //radius squared 0.061752 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "slit blocking medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
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  mua 59866.590624 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9996891514694.884766 //absorption ratio (absorbed to unabsorbed photons) in direction
of extrudelen
  //mut 59866.590624 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 10.2500000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 10.2500000  //point 1
  p2 1.0000000 1.0000000 10.2500000  //point 2
  p3 -1.0000000 1.0000000 10.2500000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000500 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "slit opening medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -0.0100000 -0.0001000 10.2500000  //point 0 (center for circle)
  p1 0.0100000 -0.0001000 10.2500000  //point 1
  p2 0.0100000 0.0001000 10.2500000  //point 2
  p3 -0.0100000 0.0001000 10.2500000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000500 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "scattering medium" //id of medium
  g 0.900000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.400000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -0.0200000 -0.0200000 10.2510000  //point 0 (center for circle)
  p1 0.0200000 -0.0200000 10.2510000  //point 1
  p2 0.0200000 0.0200000 10.2510000  //point 2
  p3 -0.0200000 0.0200000 10.2510000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator blocking medium" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 2993.329531 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 9996891514694.884766 //absorption ratio (absorbed to unabsorbed photons) in direction
of extrudelen
  //mut 2993.329531 //extinction coefficient (m^-1)
  //albedo 0.000000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype RECTANGLE //type of shape for object
  p0 -1.0000000 -1.0000000 10.2610000  //point 0 (center for circle)
  p1 1.0000000 -1.0000000 10.2610000  //point 1
  p2 1.0000000 1.0000000 10.2610000  //point 2
  p3 -1.0000000 1.0000000 10.2610000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)

Medium //define a scattering and absorbing medium
  id "collimator hole 1" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
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  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 -0.0001000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 -0.0001000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "collimator hole 2" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0000000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 0.0000000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

Medium //define a scattering and absorbing medium
  id "collimator hole 3" //id of medium
  g 1.000000 //g factor of medium (mean cosine of forward scattering angle)
  mus 0.000000 //coefficient of scattering (m^-1)
  mua 0.000000 //coefficient of absorption (m^-1)
  //scatterratio 0.000000 //scattering ratio (scattered to ballistic photons) in direction of
extrudelen
  //absorbratio 0.000000 //absorption ratio (absorbed to unabsorbed photons) in direction of
extrudelen
  //mut 0.000000 //extinction coefficient (m^-1)
  //albedo 0.500000 //albedo
  indexrefraction 1.000000 //index of refraction
  shptype CIRCLE //type of shape for object
  p0 0.0001000 0.0000000 10.2610000  //point 0 (center for circle)
  p1 0.0001000 0.0000250 10.2610000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.010000 //extrusion length (m) (0 if planar)
  //radius 0.000025 //radius of circle (m)
  //radius squared 0.000000 //radius of circle squared

PhotonSource //define a photon source
  id "uniform source 1" //id of photon source
  type UNIFORM //type of photon source
  qty 1000000 //initial number of photons in source to launch
  //qtyleft 1000000 //number of photons left in source to launch
  //count 0 //number of photons already launched from source
  wavelength 514.000000 //wavelength of photons (nm)
  shptype CIRCLE //type of shape for object
  p0 0.1000000 0.0000000 0.0000000  //point 0 (center for circle)
  p1 0.1000000 0.0012500 0.0000000  //point 1
  p2 0.0000000 0.0000000 0.0000000  //point 2
  p3 0.0000000 0.0000000 0.0000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  //radius 0.001250 //radius of circle (m)
  //radius squared 0.000002 //radius of circle squared

RunInfo
  runend Sat Dec 28 14:29:59 2002 //ending time and date of run

Map //define a photon density map
  id "x-y pos of beam before expansion" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 9.9000000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 9.9000000  //point 1
  p2 -1.0000000 -1.0000000 9.9000000  //point 2
  p3 1.0000000 -1.0000000 9.9000000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
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//	-0.012500	-0.012000	-0.011500	-0.011000	-0.010500	-0.010000
-0.009500	-0.009000	-0.008500	-0.008000	-0.007500	-0.007000	-
0.006500	-0.006000	-0.005500	-0.005000	-0.004500	-0.004000	-
0.003500	-0.003000	-0.002500	-0.002000	-0.001500	-0.001000	-
0.000500	-0.000000	0.000500	0.001000	0.001500	0.002000	
0.002500	0.003000	0.003500	0.004000	0.004500	0.005000	
0.005500	0.006000	0.006500	0.007000	0.007500	0.008000	
0.008500	0.009000	0.009500	0.010000	0.010500	0.011000	
0.011500	0.012000	0.012500				
data	16.00	19.00	19.00	10.00	14.00	9.00
14.00	20.00	14.00	8.00	24.00	12.00	8.00
13.00	11.00	8.00	15.00	8.00	8.00	16.00
11.00	16.00	8.00	12.00	6.00	9.00	17.00
5.00	18.00	17.00	15.00	13.00	11.00	8.00
14.00	8.00	11.00	6.00	18.00	8.00	16.00
11.00	22.00	15.00	14.00	20.00	14.00	18.00
12.00	15.00	14.00 //-0.012500				
\	20.00	19.00	20.00	14.00	20.00	18.00
13.00	14.00	26.00	11.00	14.00	9.00	11.00
6.00	13.00	8.00	14.00	18.00	13.00	7.00
17.00	13.00	14.00	18.00	18.00	15.00	15.00
10.00	21.00	16.00	15.00	17.00	17.00	11.00
6.00	8.00	11.00	19.00	16.00	19.00	16.00
22.00	13.00	20.00	17.00	18.00	16.00	23.00
9.00	20.00	10.00 //-0.012000				
\	19.00	14.00	20.00	13.00	16.00	18.00
13.00	21.00	14.00	7.00	19.00	15.00	10.00
13.00	7.00	16.00	12.00	16.00	13.00	14.00
14.00	10.00	15.00	12.00	11.00	9.00	12.00
20.00	9.00	15.00	20.00	13.00	16.00	16.00
7.00	14.00	14.00	11.00	13.00	16.00	17.00
13.00	19.00	13.00	20.00	11.00	15.00	20.00
24.00	20.00	10.00 //-0.011500				
\	16.00	16.00	21.00	18.00	16.00	24.00
11.00	11.00	17.00	19.00	8.00	14.00	19.00
12.00	12.00	17.00	18.00	17.00	10.00	17.00
11.00	12.00	9.00	12.00	10.00	17.00	10.00
15.00	10.00	15.00	8.00	16.00	13.00	10.00
13.00	14.00	12.00	10.00	9.00	12.00	13.00
13.00	13.00	21.00	23.00	13.00	13.00	14.00
21.00	14.00	18.00 //-0.011000				
\	17.00	15.00	22.00	10.00	15.00	16.00
13.00	18.00	12.00	10.00	9.00	16.00	19.00
17.00	24.00	13.00	13.00	15.00	4.00	12.00
12.00	14.00	11.00	5.00	18.00	11.00	5.00
12.00	18.00	10.00	15.00	18.00	9.00	10.00
12.00	11.00	17.00	12.00	14.00	11.00	6.00
11.00	13.00	20.00	18.00	20.00	20.00	19.00
16.00	18.00	12.00 //-0.010500				
\	20.00	18.00	12.00	16.00	19.00	23.00
6.00	8.00	10.00	7.00	18.00	16.00	6.00
11.00	12.00	10.00	14.00	12.00	15.00	10.00
14.00	13.00	9.00	5.00	9.00	13.00	8.00
10.00	13.00	8.00	12.00	7.00	11.00	9.00
11.00	10.00	13.00	9.00	9.00	11.00	17.00
13.00	8.00	11.00	17.00	16.00	18.00	10.00
16.00	24.00	9.00 //-0.010000				
\	21.00	12.00	17.00	15.00	14.00	6.00
15.00	15.00	7.00	8.00	15.00	9.00	11.00
13.00	6.00	16.00	13.00	16.00	9.00	7.00
5.00	1.00	5.00	1.00	3.00	5.00	3.00
0.00	2.00	5.00	10.00	10.00	16.00	14.00
12.00	14.00	13.00	10.00	7.00	24.00	15.00
16.00	16.00	10.00	12.00	16.00	21.00	16.00
30.00	15.00	21.00 //-0.009500				
\	16.00	12.00	19.00	22.00	13.00	11.00
17.00	8.00	13.00	23.00	17.00	12.00	11.00
10.00	9.00	11.00	8.00	7.00	4.00	6.00
4.00	5.00	4.00	2.00	3.00	2.00	2.00
5.00	6.00	1.00	4.00	2.00	9.00	13.00
16.00	16.00	14.00	14.00	12.00	12.00	16.00
11.00	13.00	17.00	9.00	4.00	13.00	14.00
24.00	22.00	23.00 //-0.009000				
\	15.00	14.00	15.00	8.00	8.00	11.00
11.00	11.00	16.00	12.00	19.00	12.00	15.00
11.00	11.00	6.00	2.00	1.00	2.00	3.00
3.00	7.00	7.00	3.00	6.00	6.00	3.00
3.00	4.00	4.00	3.00	3.00	2.00	5.00
10.00	1.00	13.00	13.00	14.00	11.00	14.00
21.00	16.00	11.00	14.00	7.00	16.00	14.00
19.00	16.00	14.00 //-0.008500				
\	17.00	8.00	15.00	15.00	11.00	13.00
9.00	11.00	11.00	16.00	10.00	17.00	14.00
14.00	3.00	4.00	2.00	1.00	2.00	1.00
3.00	5.00	2.00	7.00	4.00	4.00	7.00
2.00	1.00	2.00	1.00	4.00	1.00	1.00
5.00	3.00	5.00	15.00	10.00	11.00	20.00

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16.00          20.00          11.00           9.00           9.00           8.00          11.00
15.00          19.00          20.00 //-0.008000
  \             16.00           10.00          16.00          10.00          16.00          17.00
23.00           9.00          14.00          12.00          12.00          23.00           8.00
3.00           5.00           2.00           3.00           6.00           2.00           2.00
7.00           4.00           4.00           1.00           8.00           4.00           4.00
3.00           1.00           5.00           3.00           3.00           5.00           4.00
2.00           1.00           8.00           6.00          13.00          11.00           8.00
15.00           9.00          16.00          16.00          11.00          12.00          10.00
13.00          13.00          23.00 //-0.007500
  \             15.00          11.00          16.00          15.00          17.00          19.00
14.00          14.00          11.00          17.00          14.00           7.00           4.00
3.00           4.00           0.00           2.00           3.00           6.00           3.00
3.00           4.00           5.00           2.00           2.00           3.00           3.00
2.00           3.00           4.00           3.00           4.00           4.00           2.00
2.00           4.00           4.00           4.00           2.00           9.00          12.00
15.00           8.00          16.00          13.00          11.00          10.00          14.00
13.00          17.00          15.00 //-0.007000
  \             20.00          13.00          21.00           7.00          22.00          15.00
10.00          13.00          11.00          10.00          10.00           2.00           1.00
2.00           3.00           5.00           3.00           2.00           2.00           3.00
4.00           4.00           6.00           3.00           2.00           3.00           5.00
2.00           5.00           6.00           4.00           1.00           1.00           5.00
1.00           2.00           4.00           6.00           5.00           4.00          17.00
11.00          12.00          12.00          21.00           5.00          11.00          13.00
11.00          13.00          18.00 //-0.006500
  \              9.00          12.00          17.00          11.00          19.00           6.00
14.00          13.00          17.00           6.00           4.00           2.00           2.00
5.00           1.00           4.00           4.00           3.00           2.00           3.00
3.00           4.00           2.00           4.00           2.00           3.00           7.00
2.00           0.00           2.00           4.00           5.00           1.00           3.00
5.00           2.00           5.00           6.00           2.00           0.00          17.00
8.00          10.00          11.00          15.00          20.00          10.00          14.00
10.00           8.00          15.00 //-0.006000
  \             12.00           8.00           7.00          16.00          17.00          11.00
16.00          13.00          23.00           3.00           4.00           4.00           3.00
2.00           4.00           3.00           8.00           4.00           4.00           7.00
6.00           4.00           5.00           3.00           3.00           0.00           2.00
5.00           2.00           2.00           4.00           2.00           5.00           2.00
2.00           7.00           3.00           4.00           4.00           3.00           6.00
10.00           9.00          12.00          11.00          14.00          18.00          11.00
15.00           9.00          18.00 //-0.005500
  \             13.00          12.00          13.00          11.00          12.00           9.00
11.00          10.00           8.00           2.00           2.00           0.00           2.00
0.00           0.00           4.00           4.00           2.00           5.00           5.00
6.00           2.00           5.00           2.00           3.00           7.00           2.00
4.00           4.00           7.00           3.00           4.00           5.00           2.00
2.00           3.00           2.00           2.00           4.00           3.00           7.00
4.00           9.00           9.00          20.00           6.00          13.00           9.00
5.00          13.00          18.00 //-0.005000
  \             13.00          16.00          11.00          16.00          14.00           9.00
14.00          10.00           1.00           1.00           1.00           1.00           4.00
2.00           2.00           3.00           3.00           4.00           3.00           2.00
1.00           3.00           4.00          10.00          16.00          14.00          15.00
12.00           2.00           3.00           3.00           5.00           1.00           2.00
1.00           4.00           5.00           1.00           3.00           4.00           1.00
4.00           4.00          16.00          12.00          18.00          14.00          13.00
12.00          11.00          10.00 //-0.004500
  \             17.00          13.00          11.00          10.00           9.00           8.00
12.00           5.00           1.00           4.00           6.00           5.00           2.00
4.00           6.00           2.00           2.00           4.00           2.00           7.00
13.00          19.00          28.00          24.00          14.00          17.00          33.00
36.00          24.00          12.00           4.00           3.00           5.00           2.00
1.00           3.00           0.00           2.00           2.00           2.00           4.00
6.00           6.00          15.00          13.00           9.00          10.00          19.00
10.00          13.00          20.00 //-0.004000
  \             10.00          13.00          15.00          15.00          12.00          12.00
10.00           1.00           2.00           3.00           3.00           3.00           2.00
3.00           4.00           8.00           3.00           2.00           2.00          22.00
41.00          10.00           3.00           4.00           6.00           2.00           4.00
5.00           7.00          24.00          19.00           2.00           0.00           4.00
2.00           3.00           5.00           3.00           0.00           5.00           4.00
1.00           4.00          13.00          14.00          11.00          13.00          18.00
11.00          13.00          12.00 //-0.003500
  \             13.00          10.00          13.00           7.00          18.00          20.00
5.00           4.00           8.00           1.00           5.00           4.00           1.00
3.00           3.00           1.00           3.00           6.00          14.00          27.00
11.00           5.00           2.00           3.00           3.00           6.00           5.00
4.00           3.00          10.00          32.00          22.00           5.00           2.00
4.00           0.00           1.00           2.00           2.00           3.00           3.00
4.00           4.00           7.00          20.00          16.00          14.00          16.00
15.00          20.00          14.00 //-0.003000
  \             10.00          19.00          12.00          14.00          11.00          14.00
5.00           6.00           3.00           4.00           1.00           4.00           4.00
1.00           4.00           6.00           4.00          11.00          40.00           6.00
2.00           1.00           3.00           1.00           5.00           0.00           4.00
2.00           3.00           5.00           8.00          31.00          14.00           6.00
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3.00           5.00           3.00           3.00           3.00           1.00           1.00
4.00           4.00           6.00          10.00          11.00          11.00          15.00
18.00           8.00          19.00 //-0.002500
  \             7.00          21.00          11.00          17.00          12.00          11.00
4.00           3.00           1.00           1.00           2.00           6.00           0.00
5.00           4.00           2.00           1.00          27.00          20.00           5.00
3.00           4.00           3.00           1.00           2.00           7.00           5.00
2.00           3.00           6.00           7.00          15.00          25.00           5.00
3.00           1.00           2.00           5.00           3.00           2.00           3.00
2.00           5.00           1.00          18.00          15.00          14.00          14.00
14.00          17.00           9.00 //-0.002000
  \            10.00          12.00          17.00          16.00          10.00          15.00
1.00           3.00           2.00           4.00           3.00           1.00           1.00
0.00           1.00           6.00           4.00          31.00           4.00           3.00
3.00           6.00           3.00        4198.00       22793.00       22715.00        4126.00
7.00           4.00           2.00           5.00           4.00          35.00           5.00
2.00           1.00           4.00           1.00           4.00           2.00           2.00
2.00           2.00           4.00          11.00          12.00          13.00          13.00
16.00          11.00          11.00 //-0.001500
  \            19.00          18.00          16.00          13.00          14.00          11.00
6.00           2.00           1.00           1.00           2.00           2.00           2.00
5.00           2.00           4.00          15.00          19.00           5.00           2.00
5.00           1.00        4174.00       46313.00       52694.00       52649.00       46747.00
4114.00           3.00           2.00           2.00           5.00          31.00
13.00           3.00           6.00           2.00           2.00           4.00           7.00
5.00           3.00           7.00           3.00          10.00           8.00           9.00
22.00          15.00          23.00           8.00 //-0.001000
  \            19.00          18.00          14.00          12.00           8.00          11.00
6.00           4.00           4.00           5.00           1.00           3.00           2.00
6.00           2.00           3.00          17.00          21.00           3.00           4.00
6.00           4.00       23007.00       52402.00       52678.00       52947.00       52430.00
22794.00          0.00           5.00           1.00           5.00          21.00
18.00           0.00           4.00           5.00           4.00           1.00           8.00
8.00           5.00           6.00           3.00          14.00           9.00          17.00
13.00          14.00          15.00          12.00 //-0.000500
  \            10.00          21.00          10.00          17.00          20.00           7.00
7.00           0.00           1.00           3.00           3.00           4.00           3.00
4.00           5.00           2.00          23.00          22.00           1.00           2.00
3.00           3.00       22835.00       52735.00       52643.00       52608.00       52421.00
22804.00           3.00           5.00           2.00           3.00          12.00
16.00           3.00           6.00           4.00           1.00           3.00           5.00
2.00           1.00           2.00           5.00          10.00          14.00          17.00
11.00          21.00          11.00          13.00 //-0.000000
  \            20.00          15.00           7.00          14.00          14.00          10.00
3.00           4.00           2.00           3.00           3.00           8.00           6.00
2.00           3.00           1.00          10.00          18.00           4.00          10.00
3.00           5.00        4195.00       46505.00       52642.00       52666.00       46518.00
4199.00           2.00           4.00           2.00           6.00          24.00
17.00           7.00           4.00           5.00           3.00           1.00           3.00
5.00           5.00           3.00           2.00           6.00          13.00          10.00
17.00          16.00          11.00          13.00 //0.000500
  \            16.00          13.00          16.00          13.00          10.00           9.00
4.00           5.00           3.00           2.00           0.00           0.00           3.00
1.00           3.00           4.00          10.00          25.00           1.00           3.00
5.00           7.00           4.00        4154.00       22828.00       22736.00        4057.00
7.00           0.00           4.00           4.00           4.00          28.00          12.00
1.00           6.00           2.00           4.00           4.00           4.00           5.00
3.00           3.00           6.00           9.00           9.00          11.00          10.00
13.00           9.00          15.00 //0.001000
  \            13.00          11.00          11.00          12.00          15.00           8.00
4.00           5.00           3.00           4.00           3.00           2.00           7.00
2.00           0.00           6.00           3.00          28.00          15.00           4.00
2.00           4.00           1.00           4.00           3.00           1.00           7.00
2.00           4.00           1.00           5.00          17.00          28.00           2.00
2.00           5.00           3.00           2.00           5.00           1.00           3.00
2.00           3.00           7.00          16.00          10.00           8.00          13.00
16.00           8.00          15.00 //0.001500
  \            16.00          10.00          16.00          13.00          14.00          14.00
4.00           1.00           2.00           1.00           4.00           1.00           3.00
6.00           2.00           1.00           0.00           6.00          30.00           3.00
2.00           2.00           2.00           5.00           1.00           3.00           3.00
5.00           3.00           3.00           6.00          35.00          10.00           6.00
6.00           1.00           4.00           3.00           2.00           2.00           3.00
4.00           4.00           7.00          14.00          15.00          15.00          16.00
15.00           8.00          13.00 //0.002000
  \             6.00          11.00          13.00          12.00          22.00          14.00
8.00           3.00           2.00           1.00           1.00           0.00           1.00
5.00           2.00           1.00           1.00           6.00          21.00          34.00
3.00           3.00           2.00           3.00           3.00           1.00           3.00
1.00           5.00           3.00          27.00          18.00           7.00           4.00
4.00           3.00           4.00           3.00           2.00           2.00           4.00
1.00           2.00          10.00          10.00          13.00          15.00          12.00
13.00          16.00          15.00 //0.002500
  \            15.00          15.00          14.00          20.00           8.00           9.00
4.00           4.00           8.00           3.00           0.00           3.00           3.00
1.00           2.00           7.00           3.00           2.00           2.00          21.00
23.00          12.00           9.00           3.00           2.00           4.00           4.00
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1.00          7.00          27.00          18.00          0.00          4.00          5.00
6.00          4.00           3.00           4.00          2.00          0.00          4.00
6.00          2.00           5.00          16.00         12.00         11.00         13.00
13.00          9.00          12.00 //0.003000
  \            9.00           16.00          13.00         10.00         11.00         16.00
14.00          4.00           3.00           1.00          5.00          2.00          2.00
1.00          2.00           1.00           6.00          3.00          2.00          4.00
17.00         37.00          27.00          22.00         14.00         17.00         16.00
32.00         33.00           7.00           1.00          4.00          0.00          4.00
5.00          3.00           3.00           3.00          1.00          5.00          4.00
4.00          8.00          14.00          11.00         18.00         11.00         17.00
13.00          7.00           8.00 //0.003500
  \           16.00          13.00          16.00         12.00          6.00         16.00
10.00          4.00           2.00           4.00          1.00          5.00          1.00
2.00          5.00           3.00           5.00          1.00          2.00          2.00
0.00          3.00           7.00          10.00         18.00         21.00         12.00
10.00          3.00           3.00           1.00          4.00          4.00          4.00
2.00          1.00           3.00           4.00          4.00          3.00          1.00
8.00          9.00           8.00          15.00         16.00         16.00         11.00
15.00         13.00           7.00 //0.004000
  \            8.00           9.00          16.00         17.00          7.00         14.00
13.00         16.00           6.00           4.00          1.00          2.00          5.00
5.00          2.00           3.00           2.00          4.00          3.00          0.00
1.00          1.00           2.00           2.00          1.00          2.00          5.00
1.00          4.00           4.00           1.00          7.00          7.00          2.00
5.00          1.00           4.00           2.00          2.00          8.00          4.00
3.00         14.00          16.00          12.00         12.00         16.00         11.00
11.00          9.00          12.00 //0.004500
  \           12.00          12.00          10.00         12.00         14.00         23.00
10.00         11.00          11.00           8.00          1.00          5.00          1.00
4.00          2.00           2.00           4.00          4.00          6.00          3.00
7.00          5.00           3.00           7.00          5.00          6.00          5.00
1.00          6.00           3.00           4.00          5.00          1.00          3.00
1.00          2.00           3.00           3.00          7.00          5.00          2.00
8.00          5.00           6.00          20.00         10.00         11.00         13.00
6.00          8.00          19.00 //0.005000
  \            7.00          12.00           8.00         15.00         17.00         17.00
7.00         13.00          18.00           6.00          3.00          3.00          4.00
4.00          5.00           4.00           6.00          2.00          5.00          8.00
4.00          5.00           2.00           7.00          6.00          4.00          1.00
2.00          5.00           4.00           2.00          0.00          2.00          2.00
4.00          4.00           1.00           1.00          2.00          3.00          7.00
7.00         11.00          17.00          19.00         15.00         19.00          8.00
12.00         10.00          15.00 //0.005500
  \           15.00           9.00           9.00         12.00         10.00         11.00
11.00         12.00          15.00          13.00          2.00          2.00          6.00
2.00          2.00           3.00           2.00          0.00          2.00          6.00
0.00          4.00           7.00           2.00          2.00          1.00          1.00
0.00          3.00           1.00           1.00          4.00          7.00          0.00
3.00          1.00           8.00           2.00          1.00         10.00         16.00
9.00          7.00          15.00          14.00         10.00          9.00         16.00
10.00         14.00          17.00 //0.006000
  \           23.00          17.00          13.00         12.00         17.00         13.00
10.00         16.00          12.00          13.00          9.00          4.00          5.00
2.00          0.00           1.00           2.00          1.00          2.00          2.00
2.00          4.00           3.00           1.00          4.00          3.00          5.00
2.00          4.00           2.00           3.00          3.00          1.00          3.00
3.00          3.00           3.00           1.00          6.00         10.00         10.00
14.00         11.00          13.00          14.00         12.00         16.00          8.00
9.00         19.00          22.00 //0.006500
  \           24.00          18.00          12.00         17.00         13.00         14.00
12.00          7.00          16.00          10.00          9.00         10.00         11.00
0.00          2.00           3.00           3.00          0.00          2.00          2.00
1.00          3.00           7.00           2.00          1.00          3.00          2.00
3.00          4.00           1.00           8.00          3.00          1.00          2.00
3.00          4.00           1.00           4.00         12.00         13.00          9.00
13.00         12.00          16.00          10.00         10.00         11.00          9.00
13.00         24.00          12.00 //0.007000
  \           10.00          16.00          11.00         17.00         16.00         10.00
17.00         13.00          15.00          10.00         12.00         11.00         11.00
9.00          4.00           4.00           3.00          0.00          0.00          2.00
4.00          9.00           3.00           1.00          3.00          3.00          6.00
4.00          2.00           3.00           2.00          5.00          4.00          2.00
3.00          5.00           8.00          10.00         10.00         11.00         13.00
13.00         13.00           9.00          14.00         10.00         19.00         18.00
22.00         16.00          20.00 //0.007500
  \           13.00          17.00          17.00          7.00          6.00         17.00
15.00         15.00           9.00          13.00         13.00         18.00         15.00
11.00         12.00           5.00           3.00          6.00          4.00          5.00
3.00          6.00           5.00           0.00          3.00          7.00          3.00
1.00          4.00           6.00           2.00          8.00          4.00          2.00
4.00          5.00          10.00          13.00         12.00         19.00         13.00
26.00         15.00           9.00          13.00         11.00         10.00         12.00
22.00         15.00          18.00 //0.008000
  \           17.00          11.00          24.00         19.00         13.00          5.00
15.00          8.00          18.00          13.00         16.00         12.00         16.00
8.00          12.00           8.00           9.00          2.00          5.00          2.00
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3.00           4.00           5.00           7.00           2.00           3.00           3.00
0.00           6.00           1.00           3.00           0.00           6.00           9.00
14.00          15.00          12.00          11.00          14.00          11.00          20.00
17.00          13.00           6.00          18.00          18.00          12.00          16.00
15.00          23.00          18.00 //0.008500
  \             17.00          16.00           17.00          19.00          14.00           9.00
15.00          11.00          12.00          12.00          15.00          22.00          18.00
12.00          20.00          18.00          15.00           8.00          12.00           3.00
4.00           2.00           3.00           5.00           3.00           3.00           3.00
5.00           3.00           6.00           9.00          12.00          11.00          12.00
14.00           9.00          13.00          14.00           9.00          16.00           8.00
10.00           5.00          19.00          10.00          15.00          18.00          12.00
15.00          18.00          17.00 //0.009000
  \             24.00          20.00           24.00          13.00          18.00           8.00
13.00           9.00          13.00          11.00          13.00          18.00          15.00
12.00          12.00          12.00           8.00          14.00          12.00           6.00
7.00           15.00          11.00           8.00          11.00           6.00           8.00
9.00           9.00           16.00          12.00          20.00          11.00          10.00
12.00          11.00          13.00           10.00          15.00          18.00           9.00
7.00           7.00           9.00           12.00          17.00          20.00          20.00
13.00          15.00          17.00 //0.009500
  \             19.00          16.00           20.00          15.00          17.00          15.00
18.00           8.00           9.00          11.00          10.00          15.00           9.00
21.00          19.00          14.00           6.00          13.00          13.00           7.00
11.00           9.00           9.00          10.00          12.00           9.00          12.00
8.00           11.00          20.00          12.00          10.00           9.00          10.00
13.00          20.00          10.00           24.00          15.00          13.00          19.00
9.00           10.00          15.00          17.00          16.00          24.00          17.00
17.00          14.00          25.00 //0.010000
  \             23.00          19.00           13.00          15.00          18.00          20.00
20.00          21.00           7.00           9.00           12.00          15.00          15.00
9.00           20.00          14.00          15.00           6.00           5.00          11.00
12.00          14.00          13.00           16.00          9.00           13.00          12.00
14.00           9.00          17.00           8.00          21.00          13.00          18.00
11.00          11.00          11.00          12.00          15.00          16.00           9.00
13.00          10.00          13.00          14.00          16.00          12.00          13.00
15.00          18.00          13.00 //0.010500
  \             14.00          23.00           16.00          12.00          14.00          16.00
17.00          11.00          14.00          11.00          13.00          12.00          17.00
9.00           16.00          17.00          10.00          21.00          11.00          11.00
16.00          15.00           6.00          12.00           9.00           8.00          14.00
16.00          14.00          21.00          14.00          17.00          12.00          11.00
13.00          15.00          14.00          15.00           9.00          17.00           9.00
21.00          20.00          13.00          20.00          15.00          21.00          23.00
17.00          15.00          19.00 //0.011000
  \             14.00          17.00           17.00          17.00          14.00          19.00
27.00          19.00          21.00          17.00          16.00           6.00          11.00
17.00          18.00           7.00           6.00          20.00          12.00           8.00
13.00          10.00          11.00          18.00          20.00          21.00          18.00
12.00          14.00          17.00          16.00          13.00          11.00           9.00
17.00          10.00          11.00          15.00          10.00          14.00          18.00
21.00          11.00          18.00          19.00          22.00          14.00          27.00
23.00          17.00          21.00 //0.011500
  \             17.00          10.00           23.00          20.00          20.00          14.00
13.00          16.00          10.00          20.00          14.00          14.00          14.00
16.00          11.00          14.00          14.00          10.00          21.00          12.00
15.00          10.00          11.00          10.00          10.00          12.00          18.00
11.00          11.00          15.00           4.00          14.00          13.00          11.00
8.00           14.00          10.00          12.00          22.00          12.00          13.00
22.00          23.00          17.00          21.00          27.00          20.00          12.00
13.00          23.00          22.00 //0.012000
  \              9.00          19.00           17.00          15.00          16.00          22.00
16.00          13.00          27.00          18.00          17.00          14.00          13.00
14.00          16.00           9.00          17.00           9.00          12.00          16.00
7.00           14.00          10.00          16.00          14.00          10.00           8.00
8.00           15.00          10.00          11.00          13.00          17.00          16.00
16.00          21.00          27.00          15.00          23.00          14.00          22.00
12.00          15.00          11.00          18.00          18.00          20.00          16.00
15.00          18.00          21.00 //0.012500

Map //define a photon density map
  id "x-y pos of beam after expansion" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2490000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2490000  //point 1
  p2 -1.0000000 -1.0000000 10.2490000  //point 2
  p3 1.0000000 -1.0000000 10.2490000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
  //         -0.012500       -0.012000       -0.011500       -0.011000       -0.010500       -0.010000
-0.009500       -0.009000       -0.008500       -0.008000       -0.007500       -0.007000       -
0.006500       -0.006000       -0.005500       -0.005000       -0.004500       -0.004000       -
0.003500       -0.003000       -0.002500       -0.002000       -0.001500       -0.001000       -
0.000500       -0.000000        0.000500        0.001000        0.001500        0.002000
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0.002500        0.003000        0.003500        0.004000        0.004500        0.005000
0.005500        0.006000        0.006500        0.007000        0.007500        0.008000
0.008500        0.009000        0.009500        0.010000        0.010500        0.011000
0.011500        0.012000        0.012500
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            1.00            0.00
0.00            2.00            0.00            1.00            0.00           74.00          145.00
252.00          278.00          341.00          355.00          393.00          372.00          387.00
335.00          279.00          234.00          176.00           56.00            1.00            0.00
2.00            1.00            0.00            0.00            0.00            1.00            1.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            1.00            0.00 //-0.012500
  \               0.00            0.00            0.00            0.00            0.00            1.00
0.00            0.00            0.00            0.00            2.00            1.00            0.00
2.00            1.00           62.00          207.00          337.00          328.00          370.00
363.00          377.00          377.00          409.00          358.00          372.00          366.00
371.00          341.00          359.00          380.00          349.00          316.00          193.00
53.00            0.00            0.00            0.00            0.00            0.00            0.00
1.00            1.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            2.00 //-0.012000
  \               1.00            1.00            0.00            0.00            0.00            0.00
0.00            0.00            1.00            0.00            0.00            3.00            0.00
74.00          252.00          391.00          356.00          376.00          363.00          369.00
388.00          385.00          354.00          374.00          406.00          347.00          381.00
369.00          343.00          363.00          403.00          360.00          361.00          372.00
344.00          229.00           89.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            1.00            0.00 //-0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00           48.00          245.00
369.00          356.00          394.00          387.00          392.00          386.00          392.00
374.00          384.00          314.00          392.00          373.00          374.00          357.00
407.00          381.00          362.00          375.00          354.00          367.00          355.00
350.00          397.00          372.00          264.00           35.00            0.00            0.00
0.00            0.00            0.00            0.00            1.00            0.00            0.00
0.00            0.00            0.00 //-0.011000
  \               0.00            0.00            0.00            0.00            2.00            0.00
0.00            0.00            0.00            1.00          145.00          377.00          399.00
375.00          356.00          379.00          371.00          333.00          381.00          350.00
360.00          388.00          389.00          359.00          379.00          404.00          363.00
391.00          355.00          361.00          401.00          374.00          365.00          406.00
401.00          367.00          371.00          368.00          326.00          151.00            2.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            7.00          221.00          416.00          352.00          397.00
343.00          384.00          356.00          368.00          379.00          382.00          361.00
374.00          375.00          383.00          374.00          400.00          385.00          362.00
372.00          390.00          372.00          360.00          394.00          360.00          374.00
380.00          367.00          352.00          363.00          361.00          392.00          239.00
6.00            0.00            0.00            0.00            0.00            1.00            0.00
0.00            0.00            0.00 //-0.010000
  \               0.00            0.00            1.00            1.00            0.00            1.00
0.00           21.00          291.00          368.00          362.00          356.00          369.00
380.00          374.00          366.00          381.00          351.00          411.00          381.00
328.00          362.00          370.00          373.00          374.00          377.00          388.00
373.00          399.00          361.00          366.00          346.00          381.00          423.00
394.00          368.00          396.00          366.00          407.00          351.00          359.00
289.00           26.00            1.00            1.00            1.00            0.00            1.00
0.00            0.00            0.00 //-0.009500
  \               0.00            0.00            1.00            0.00            1.00            1.00
31.00          290.00          390.00          361.00          385.00          397.00          375.00
352.00          438.00          403.00          381.00          391.00          406.00          384.00
387.00          391.00          403.00          388.00          405.00          368.00          409.00
381.00          387.00          383.00          383.00          371.00          368.00          383.00
387.00          375.00          345.00          362.00          385.00          385.00          394.00
384.00          305.00           16.00            0.00            1.00            0.00            2.00
0.00            0.00            0.00 //-0.009000
  \               1.00            0.00            0.00            0.00            0.00            4.00
287.00          359.00          343.00          341.00          353.00          368.00          371.00
362.00          407.00          389.00          392.00          388.00          358.00          380.00
416.00          364.00          355.00          372.00          381.00          393.00          375.00
342.00          364.00          397.00          411.00          360.00          400.00          349.00
389.00          401.00          368.00          373.00          339.00          382.00          380.00
397.00          354.00          287.00           12.00            0.00            0.00            1.00
0.00            0.00            0.00 //-0.008500
  \               1.00            0.00            0.00            0.00            0.00          242.00
350.00          344.00          401.00          354.00          357.00          370.00          379.00
356.00          362.00          352.00          388.00          343.00          361.00          396.00
373.00          384.00          361.00          373.00          348.00          385.00          366.00
353.00          326.00          388.00          368.00          378.00          374.00          384.00
404.00          372.00          398.00          344.00          351.00          387.00          388.00
367.00          375.00          368.00          228.00            0.00            1.00            0.00
0.00            0.00            0.00 //-0.008000
  \               0.00            0.00            0.00            0.00          139.00          319.00
375.00          360.00          398.00          397.00          346.00          388.00          355.00
359.00          383.00          388.00          359.00          370.00          344.00          379.00
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385.00          387.00          399.00          362.00          406.00          403.00          386.00
401.00          390.00          352.00          384.00          385.00          367.00          391.00
375.00          371.00          391.00          356.00          373.00          364.00          385.00
398.00          341.00          373.00          366.00          142.00            0.00            1.00
1.00            1.00            1.00 //-0.007500
  \               1.00            1.00            1.00           39.00          357.00          348.00
372.00          364.00          371.00          364.00          352.00          345.00          403.00
375.00          390.00          353.00          390.00          363.00          375.00          403.00
403.00          386.00          378.00          398.00          393.00          392.00          390.00
390.00          415.00          406.00          431.00          370.00          364.00          343.00
365.00          382.00          381.00          372.00          380.00          361.00          369.00
374.00          387.00          378.00          361.00          339.00           38.00            0.00
1.00            1.00            0.00 //-0.007000
  \               2.00            0.00            0.00          216.00          405.00          358.00
366.00          389.00          377.00          343.00          373.00          368.00          370.00
386.00          378.00          376.00          380.00          357.00          387.00          410.00
389.00          409.00          376.00          379.00          366.00          377.00          403.00
401.00          407.00          392.00          401.00          374.00          406.00          342.00
374.00          335.00          373.00          369.00          356.00          331.00          375.00
379.00          386.00          371.00          402.00          385.00          257.00            0.00
0.00            0.00            0.00 //-0.006500
  \               0.00            0.00           73.00          355.00          370.00          350.00
361.00          379.00          421.00          404.00          362.00          393.00          374.00
377.00          373.00          404.00          357.00          389.00          355.00          408.00
373.00          394.00          396.00          416.00          402.00          384.00          372.00
411.00          400.00          398.00          412.00          404.00          411.00          430.00
347.00          380.00          365.00          381.00          355.00          373.00          391.00
368.00          352.00          370.00          375.00          350.00          370.00           89.00
0.00            2.00            0.00 //-0.006000
  \               0.00            0.00          272.00          362.00          386.00          366.00
375.00          351.00          348.00          379.00          358.00          356.00          372.00
375.00          365.00          367.00          401.00          397.00          432.00          400.00
404.00          400.00          406.00          331.00          404.00          385.00          369.00
413.00          374.00          360.00          368.00          417.00          378.00          381.00
423.00          354.00          357.00          386.00          354.00          337.00          382.00
381.00          376.00          359.00          396.00          376.00          353.00          259.00
1.00            0.00            0.00 //-0.005500
  \               0.00           57.00          363.00          382.00          399.00          389.00
332.00          366.00          387.00          374.00          361.00          391.00          368.00
375.00          396.00          421.00          368.00          371.00          404.00          393.00
386.00          358.00          412.00          390.00          407.00          390.00          426.00
411.00          438.00          434.00          408.00          385.00          399.00          403.00
411.00          403.00          394.00          358.00          353.00          357.00          386.00
397.00          342.00          427.00          378.00          382.00          386.00          356.00
54.00            0.00            0.00 //-0.005000
  \               0.00          174.00          368.00          384.00          398.00          413.00
369.00          357.00          364.00          341.00          361.00          371.00          407.00
338.00          409.00          407.00          366.00          385.00          398.00          437.00
367.00          380.00          389.00          414.00          382.00          394.00          394.00
402.00          384.00          435.00          403.00          387.00          400.00          408.00
386.00          406.00          379.00          413.00          369.00          412.00          390.00
370.00          367.00          392.00          363.00          349.00          391.00          360.00
205.00            0.00            1.00 //-0.004500
  \               0.00          298.00          376.00          366.00          347.00          377.00
363.00          363.00          398.00          361.00          375.00          374.00          369.00
380.00          415.00          397.00          395.00          390.00          395.00          356.00
364.00          410.00          386.00          396.00          444.00          387.00          417.00
388.00          380.00          394.00          356.00          387.00          402.00          390.00
408.00          394.00          405.00          355.00          394.00          371.00          419.00
377.00          389.00          390.00          395.00          345.00          356.00          371.00
333.00            0.00            2.00 //-0.004000
  \              61.00          383.00          357.00          429.00          375.00          342.00
428.00          355.00          344.00          331.00          345.00          334.00          376.00
379.00          368.00          402.00          409.00          405.00          415.00          412.00
386.00          353.00          385.00          372.00          408.00          379.00          392.00
428.00          415.00          380.00          388.00          370.00          393.00          394.00
375.00          361.00          383.00          353.00          351.00          401.00          404.00
346.00          377.00          354.00          387.00          334.00          368.00          418.00
338.00           52.00            0.00 //-0.003500
  \             155.00          388.00          397.00          388.00          403.00          374.00
360.00          388.00          352.00          363.00          365.00          380.00          363.00
431.00          402.00          376.00          388.00          384.00          419.00          367.00
384.00          414.00          367.00          404.00          411.00          467.00          409.00
373.00          432.00          401.00          373.00          363.00          385.00          434.00
388.00          398.00          358.00          370.00          381.00          387.00          364.00
345.00          394.00          393.00          389.00          361.00          369.00          364.00
361.00          125.00            0.00 //-0.003000
  \             233.00          370.00          350.00          372.00          368.00          404.00
380.00          407.00          385.00          381.00          379.00          373.00          380.00
384.00          366.00          429.00          374.00          413.00          396.00          394.00
383.00          418.00          412.00          376.00          364.00          416.00          390.00
358.00          403.00          405.00          379.00          380.00          377.00          408.00
429.00          347.00          407.00          431.00          394.00          383.00          380.00
336.00          358.00          356.00          370.00          383.00          386.00          356.00
377.00          225.00            0.00 //-0.002500
  \             294.00          359.00          388.00          373.00          361.00          397.00
362.00          361.00          389.00          350.00          402.00          403.00          415.00
```

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414.00          396.00          421.00          387.00          362.00          422.00          380.00
380.00          386.00          411.00          394.00          419.00          402.00          426.00
414.00          423.00          420.00          417.00          384.00          370.00          401.00
380.00          385.00          396.00          390.00          393.00          354.00          363.00
349.00          356.00          320.00          365.00          352.00          367.00          382.00
351.00          318.00            1.00 //-0.002000
  \             317.00          357.00          418.00          355.00          374.00          374.00
373.00          369.00          384.00          413.00          362.00          390.00          392.00
358.00          398.00          401.00          387.00          366.00          412.00          379.00
403.00          374.00          390.00          386.00          406.00          394.00          430.00
366.00          412.00          397.00          403.00          390.00          365.00          394.00
395.00          409.00          390.00          397.00          431.00          366.00          374.00
387.00          375.00          357.00          378.00          384.00          337.00          394.00
386.00          332.00            0.00 //-0.001500
  \             349.00          372.00          363.00          396.00          383.00          378.00
382.00          377.00          371.00          362.00          391.00          395.00          380.00
385.00          379.00          391.00          398.00          405.00          384.00          409.00
409.00          440.00          377.00          362.00          392.00          399.00          392.00
394.00          393.00          379.00          431.00          412.00          386.00          382.00
364.00          385.00          408.00          375.00          409.00          358.00          351.00
361.00          355.00          359.00          365.00          383.00          388.00          370.00
380.00          388.00            0.00 //-0.001000
  \             361.00          344.00          356.00          374.00          362.00          401.00
367.00          400.00          345.00          367.00          385.00          413.00          394.00
392.00          418.00          382.00          383.00          419.00          400.00          403.00
406.00          377.00          391.00          382.00          408.00          396.00          391.00
406.00          378.00          425.00          409.00          405.00          412.00          392.00
404.00          400.00          416.00          415.00          405.00          365.00          392.00
405.00          368.00          415.00          343.00          351.00          390.00          374.00
367.00          410.00            8.00 //-0.000500
  \             370.00          392.00          361.00          367.00          349.00          349.00
364.00          364.00          426.00          411.00          335.00          411.00          409.00
399.00          376.00          381.00          393.00          441.00          435.00          364.00
341.00          380.00          409.00          418.00          431.00          390.00          361.00
387.00          387.00          392.00          432.00          411.00          407.00          374.00
417.00          437.00          371.00          347.00          404.00          390.00          376.00
411.00          347.00          342.00          389.00          369.00          405.00          381.00
349.00          370.00            5.00 //-0.000000
  \             391.00          365.00          370.00          352.00          386.00          385.00
357.00          357.00          401.00          366.00          410.00          366.00          407.00
399.00          409.00          404.00          358.00          430.00          437.00          405.00
398.00          351.00          361.00          392.00          364.00          383.00          393.00
381.00          397.00          342.00          420.00          380.00          405.00          412.00
415.00          373.00          406.00          398.00          380.00          377.00          362.00
358.00          370.00          344.00          371.00          353.00          348.00          376.00
382.00          339.00            0.00 //0.000500
  \             351.00          373.00          337.00          389.00          373.00          375.00
351.00          378.00          364.00          388.00          375.00          386.00          429.00
410.00          362.00          383.00          385.00          366.00          391.00          376.00
376.00          386.00          397.00          408.00          399.00          401.00          427.00
374.00          416.00          374.00          357.00          381.00          376.00          365.00
369.00          396.00          353.00          372.00          362.00          367.00          353.00
354.00          351.00          365.00          369.00          330.00          369.00          379.00
378.00          361.00            0.00 //0.001000
  \             300.00          380.00          392.00          389.00          393.00          366.00
365.00          328.00          393.00          362.00          378.00          399.00          401.00
377.00          411.00          409.00          393.00          410.00          413.00          396.00
420.00          411.00          405.00          417.00          383.00          374.00          392.00
412.00          376.00          383.00          397.00          421.00          386.00          401.00
418.00          388.00          383.00          393.00          421.00          386.00          377.00
355.00          330.00          352.00          377.00          392.00          332.00          418.00
396.00          286.00            0.00 //0.001500
  \             248.00          379.00          358.00          379.00          354.00          403.00
354.00          375.00          354.00          369.00          392.00          376.00          403.00
408.00          408.00          396.00          404.00          421.00          386.00          370.00
408.00          377.00          389.00          402.00          374.00          418.00          369.00
410.00          408.00          354.00          408.00          371.00          406.00          407.00
401.00          350.00          432.00          384.00          417.00          367.00          379.00
358.00          383.00          367.00          405.00          328.00          360.00          344.00
368.00          245.00            0.00 //0.002000
  \             133.00          400.00          360.00          390.00          397.00          386.00
364.00          380.00          371.00          376.00          405.00          373.00          417.00
402.00          381.00          393.00          393.00          400.00          379.00          422.00
339.00          401.00          383.00          402.00          387.00          398.00          419.00
358.00          360.00          376.00          391.00          394.00          389.00          376.00
352.00          409.00          376.00          403.00          363.00          377.00          401.00
409.00          385.00          367.00          364.00          359.00          336.00          367.00
393.00          142.00            0.00 //0.002500
  \              45.00          351.00          368.00          384.00          370.00          330.00
377.00          376.00          385.00          415.00          389.00          368.00          408.00
403.00          401.00          403.00          416.00          407.00          371.00          420.00
358.00          412.00          405.00          384.00          366.00          385.00          396.00
409.00          403.00          436.00          387.00          409.00          377.00          389.00
395.00          391.00          389.00          409.00          367.00          403.00          383.00
392.00          347.00          397.00          375.00          376.00          368.00          385.00
407.00           56.00            0.00 //0.003000
```

```
  \              2.00          309.00          335.00          381.00          357.00          391.00
377.00          379.00          405.00          378.00          367.00          401.00          385.00
378.00          410.00          394.00          447.00          413.00          431.00          424.00
372.00          415.00          409.00          402.00          394.00          432.00          396.00
369.00          400.00          405.00          408.00          361.00          413.00          425.00
395.00          362.00          403.00          371.00          397.00          371.00          366.00
371.00          367.00          373.00          373.00          366.00          399.00          384.00
291.00            0.00            1.00 //0.003500
  \              0.00          190.00          384.00          354.00          363.00          370.00
354.00          363.00          371.00          379.00          364.00          356.00          380.00
398.00          379.00          363.00          385.00          381.00          415.00          375.00
386.00          373.00          366.00          396.00          383.00          389.00          383.00
390.00          404.00          384.00          382.00          368.00          390.00          394.00
390.00          382.00          392.00          378.00          362.00          388.00          389.00
399.00          399.00          378.00          378.00          369.00          365.00          366.00
215.00            1.00            0.00 //0.004000
  \              1.00           39.00          400.00          347.00          376.00          359.00
334.00          396.00          344.00          389.00          361.00          393.00          358.00
365.00          369.00          393.00          397.00          428.00          395.00          394.00
349.00          374.00          400.00          398.00          367.00          357.00          421.00
402.00          409.00          401.00          414.00          380.00          412.00          394.00
416.00          373.00          383.00          390.00          377.00          373.00          371.00
374.00          369.00          399.00          371.00          394.00          385.00          398.00
50.00            0.00            0.00 //0.004500
  \              0.00            1.00          239.00          371.00          357.00          389.00
372.00          394.00          317.00          343.00          369.00          339.00          366.00
410.00          396.00          414.00          378.00          401.00          396.00          389.00
400.00          349.00          349.00          430.00          386.00          374.00          452.00
342.00          382.00          388.00          381.00          385.00          396.00          393.00
402.00          393.00          395.00          373.00          388.00          404.00          378.00
364.00          386.00          344.00          353.00          347.00          394.00          232.00
0.00            0.00            1.00 //0.005000
  \              0.00            1.00           96.00          380.00          358.00          360.00
357.00          391.00          370.00          361.00          389.00          379.00          345.00
403.00          343.00          399.00          405.00          374.00          374.00          390.00
377.00          403.00          422.00          356.00          359.00          372.00          408.00
421.00          368.00          383.00          414.00          401.00          411.00          354.00
384.00          368.00          355.00          383.00          362.00          401.00          354.00
345.00          378.00          373.00          372.00          407.00          363.00           75.00
1.00            0.00            2.00 //0.005500
  \              0.00            2.00            1.00          242.00          381.00          361.00
346.00          369.00          347.00          366.00          368.00          428.00          361.00
387.00          397.00          365.00          376.00          382.00          386.00          370.00
431.00          398.00          418.00          432.00          367.00          401.00          384.00
365.00          357.00          392.00          385.00          373.00          397.00          369.00
366.00          392.00          369.00          400.00          364.00          347.00          396.00
398.00          380.00          364.00          386.00          409.00          231.00            0.00
0.00            0.00            1.00 //0.006000
  \              0.00            0.00            0.00           38.00          386.00          369.00
364.00          371.00          349.00          402.00          381.00          382.00          361.00
343.00          350.00          392.00          373.00          365.00          371.00          389.00
389.00          387.00          407.00          411.00          435.00          400.00          380.00
383.00          390.00          371.00          380.00          361.00          380.00          353.00
416.00          371.00          341.00          364.00          372.00          376.00          378.00
346.00          388.00          348.00          365.00          331.00           35.00            1.00
0.00            1.00            0.00 //0.006500
  \              1.00            0.00            0.00            2.00          142.00          375.00
390.00          392.00          390.00          366.00          345.00          390.00          381.00
354.00          368.00          385.00          392.00          353.00          388.00          375.00
384.00          391.00          361.00          371.00          413.00          380.00          344.00
374.00          379.00          392.00          388.00          388.00          379.00          371.00
395.00          361.00          386.00          374.00          378.00          382.00          354.00
369.00          359.00          367.00          333.00          138.00            0.00            0.00
0.00            0.00            0.00 //0.007000
  \              1.00            0.00            0.00            1.00            1.00          238.00
395.00          383.00          369.00          385.00          350.00          351.00          397.00
354.00          351.00          371.00          361.00          348.00          400.00          410.00
380.00          364.00          389.00          390.00          354.00          353.00          371.00
377.00          392.00          371.00          397.00          373.00          400.00          381.00
367.00          380.00          403.00          368.00          376.00          336.00          369.00
374.00          405.00          330.00          232.00            0.00            0.00            0.00
0.00            1.00            0.00 //0.007500
  \              0.00            1.00            0.00            0.00            0.00           10.00
281.00          363.00          363.00          387.00          379.00          371.00          389.00
367.00          370.00          383.00          377.00          368.00          379.00          392.00
364.00          388.00          383.00          380.00          385.00          388.00          371.00
361.00          381.00          335.00          400.00          388.00          384.00          355.00
364.00          360.00          385.00          362.00          381.00          354.00          359.00
367.00          345.00          276.00           11.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.008000
  \              0.00            0.00            1.00            0.00            0.00            0.00
24.00         304.00          359.00          370.00          358.00          400.00          388.00
394.00          398.00          364.00          330.00          329.00          354.00          367.00
377.00          366.00          382.00          408.00          373.00          378.00          347.00
390.00          353.00          395.00          401.00          383.00          360.00          403.00
383.00          367.00          388.00          377.00          353.00          344.00          397.00
```

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347.00          283.00           23.00            0.00            0.00            0.00            1.00
0.00            0.00           0.00 //0.008500
  \               0.00            0.00            0.00            0.00            0.00            0.00
1.00           25.00          263.00          350.00          349.00          337.00          373.00
410.00          379.00           389.00          365.00          397.00          362.00          373.00
378.00          342.00           386.00          384.00          375.00          365.00          389.00
386.00          366.00           382.00          368.00          364.00          405.00          397.00
371.00          396.00           377.00          334.00          412.00          408.00          397.00
281.00           26.00            1.00            0.00            0.00            0.00            0.00
0.00            0.00           0.00 //0.009000
  \               0.00            0.00            0.00            1.00            2.00            2.00
0.00            1.00           13.00          240.00          381.00          344.00          374.00
384.00          350.00           361.00          380.00          353.00          338.00          395.00
369.00          378.00           344.00          395.00          409.00          384.00          388.00
373.00          378.00           379.00          375.00          352.00          370.00          374.00
383.00          385.00           378.00          368.00          391.00          355.00          240.00
11.00            0.00             2.00            0.00            0.00            0.00            0.00
0.00            0.00           0.00 //0.009500
  \               0.00            0.00            0.00            0.00            1.00            0.00
2.00            1.00             1.00            0.00          159.00          331.00          360.00
341.00          386.00           355.00          387.00          357.00          362.00          385.00
395.00          373.00           380.00          404.00          375.00          361.00          373.00
382.00          388.00           389.00          367.00          380.00          350.00          371.00
375.00          352.00           345.00          359.00          361.00          138.00            0.00
0.00            1.00             0.00            1.00            0.00            1.00            0.00
0.00            0.00           0.00 //0.010000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00             0.00            0.00            2.00           36.00          280.00
345.00          373.00           358.00          344.00          304.00          344.00          380.00
398.00          339.00           391.00          390.00          364.00          346.00          357.00
354.00          372.00           348.00          357.00          375.00          356.00          359.00
351.00          355.00           374.00          231.00           40.00            1.00            1.00
1.00            2.00             0.00            0.00            0.00            0.00            0.00
0.00            1.00           1.00 //0.010500
  \               1.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00             0.00            0.00            0.00            0.00            0.00
82.00          258.00           348.00          376.00          381.00          399.00          378.00
355.00          399.00           357.00          374.00          382.00          397.00          362.00
329.00          365.00           352.00          368.00          356.00          375.00          395.00
358.00          261.00            59.00            2.00            0.00            1.00            0.00
1.00            0.00             0.00            0.00            0.00            0.00            0.00
0.00            1.00           0.00 //0.011000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00             1.00            0.00            1.00            0.00            0.00
0.00            0.00            52.00          196.00          324.00          359.00          369.00
383.00          367.00           388.00          403.00          355.00          392.00          373.00
355.00          374.00           370.00          397.00          377.00          313.00          197.00
56.00            0.00             0.00            0.00            1.00            0.00            0.00
0.00            0.00             0.00            0.00            0.00            0.00            0.00
0.00            1.00           0.00 //0.011500
  \               1.00            1.00            3.00            0.00            0.00            0.00
0.00            0.00             0.00            0.00            0.00            0.00            1.00
0.00            0.00             1.00            0.00            0.00           69.00          169.00
233.00          301.00           333.00          341.00          368.00          385.00          350.00
365.00          291.00           209.00          164.00           63.00            1.00            0.00
0.00            0.00             1.00            2.00            0.00            1.00            0.00
0.00            0.00             0.00            0.00            0.00            0.00            0.00
1.00            0.00           1.00 //0.012000
  \               0.00            0.00            0.00            0.00            1.00            0.00
0.00            0.00             0.00            0.00            0.00            0.00            0.00
0.00            2.00             0.00            1.00            0.00            0.00            0.00
0.00            0.00             0.00            0.00            3.00            1.00            0.00
0.00            0.00             0.00            1.00            0.00            0.00            0.00
1.00            0.00             0.00            0.00            0.00            1.00            0.00
0.00            0.00             0.00            0.00            1.00            1.00            0.00
1.00            0.00           0.00 //0.012500

Map //define a photon density map
  id "x-y pos of beam upstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2610000  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2610000  //point 1
  p2 -1.0000000 -1.0000000 10.2610000  //point 2
  p3 1.0000000 -1.0000000 10.2610000  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.012500 0.012500 0.000500 //row index
  idxcol "col index1" HASH PHOTPOSX -0.012500 0.012500 0.000500 //column index
  //         -0.012500       -0.012000       -0.011500       -0.011000       -0.010500       -0.010000
-0.009500       -0.009000       -0.008500       -0.008000       -0.007500       -0.007000       -
0.006500       -0.006000       -0.005500       -0.005000       -0.004500       -0.004000       -
0.003500       -0.003000       -0.002500       -0.002000       -0.001500       -0.001000       -
0.000500       -0.000000        0.000500        0.001000        0.001500        0.002000
0.002500        0.003000        0.003500        0.004000        0.004500        0.005000
0.005500        0.006000        0.006500        0.007000        0.007500        0.008000
```

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0.008500        0.009000        0.009500        0.010000        0.010500        0.011000
0.011500        0.012000        0.012500
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.012000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.011500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.011000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.010000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.009500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.009000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.008500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.008000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.007500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.007000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.006500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.006000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //-0.005500
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.005000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.004500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //-0.004000
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0.00            0.00            0.00 //-0.003500
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.003000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.002500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //-0.001500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.001000
  \               0.00            0.00            0.00            0.00            1.00           81.00
84.00           66.00           76.00           61.00           85.00           60.00           84.00
79.00           86.00           73.00           86.00           79.00           79.00           70.00
78.00           60.00           60.00           79.00           77.00           78.00           81.00
97.00           81.00           76.00           79.00           79.00           84.00           70.00
89.00           82.00           67.00           73.00           82.00           64.00           65.00
78.00           78.00           90.00           69.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.000500
  \               0.00            0.00            0.00            0.00            0.00           79.00
60.00           80.00           80.00           83.00           55.00           77.00           65.00
70.00           62.00           72.00           81.00           76.00           87.00           82.00
79.00           87.00           72.00           84.00           83.00           88.00           82.00
78.00           87.00           72.00           75.00           76.00           90.00           68.00
80.00           97.00           78.00           61.00           71.00           75.00           66.00
74.00           60.00           75.00           89.00            0.00            0.00            0.00
0.00            0.00            0.00 //-0.000000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //0.000500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.001000
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.001500
  \               0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.002000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.002500
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.003000
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.003500
  \             0.00          0.00            0.00          0.00          0.00          0.00
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0.00          0.00          0.00          0.00          0.00          0.00          0.00
0.00          0.00          0.00 //0.004000
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0.00          0.00          0.00 //0.005000
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  \             0.00          0.00            0.00          0.00          0.00          0.00
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0.00            0.00            0.00 //0.009000
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00 //0.009500
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  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00 //0.012500

Map //define a photon density map
  id "x-y pos downstream of collimating hole" //id of density map
  type PLANAR //type of density map
  shptype RECTANGLE //type of shape for object
  p0 1.0000000 1.0000000 10.2710010  //point 0 (center for circle)
  p1 -1.0000000 1.0000000 10.2710010  //point 1
  p2 -1.0000000 -1.0000000 10.2710010  //point 2
  p3 1.0000000 -1.0000000 10.2710010  //point 3
  normalvector 0.0000000 0.0000000 1.0000000  //surface normal
  extrudelen 0.000000 //extrusion length (m) (0 if planar)
  idxrow "row index1" HASH PHOTPOSY -0.000050 0.000050 0.000005 //row index
  idxcol "col index1" HASH PHOTPOSX -0.000150 0.000150 0.000005 //column index
  //         -0.000150       -0.000145       -0.000140       -0.000135       -0.000130       -0.000125
-0.000120       -0.000115       -0.000110       -0.000105       -0.000100       -0.000095       -
0.000090       -0.000085       -0.000080       -0.000075       -0.000070       -0.000065       -
0.000060       -0.000055       -0.000050       -0.000045       -0.000040       -0.000035       -
0.000030       -0.000025       -0.000020       -0.000015       -0.000010       -0.000005
0.000000        0.000005        0.000010        0.000015        0.000020        0.000025
0.000030        0.000035        0.000040        0.000045        0.000050        0.000055
0.000060        0.000065        0.000070        0.000075        0.000080        0.000085
0.000090        0.000095        0.000100        0.000105        0.000110        0.000115
0.000120        0.000125        0.000130        0.000135        0.000140        0.000145
  data            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00 //-0.000050
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0.00            0.00            0.00            0.00            0.00 //-0.000045
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000040
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000035
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00 //-0.000025
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000020
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00 //-0.000015
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0.00            0.00            0.00            0.00            0.00 //-0.000010
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0.00            0.00            0.00            0.00            1.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //-0.000005
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00 //0.000000
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0.00            0.00            0.00            0.00            0.00 //0.000005
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0.00            0.00            0.00            0.00            0.00 //0.000010
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0.00            0.00            0.00            0.00            0.00 //0.000015
  \               0.00            0.00            0.00            0.00            0.00            0.00
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0.00            0.00            0.00            0.00            0.00 //0.000030
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000040
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0.00            0.00            0.00            0.00            0.00 //0.000045
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0.00            0.00            0.00            0.00            0.00            0.00            0.00
0.00            0.00            0.00            0.00            0.00 //0.000050
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